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Civil Engineering

# ASSESSMENT OF HYBRID RC BUILDING HAVING VARIOUS BEARING ISOLATORS

**Mohammed Hashim JANABI**

Master's Thesis

Supervisor

Prof. Dr. Zeki HASGÜR

Istanbul, 2023

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The thesis titled ASSESSMENT OF HYBRID RC BUILDING HAVING VARIOUS BEARING ISOLATORS prepared by MOHAMMED JANABI and submitted on 7/4/2023 has been **accepted unanimously** for the degree of Master of Science in Civil Engineering.

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I hereby declare that this thesis meets all format and submission requirements of a Master's thesis.

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I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Mohammed Hashim JANABI

Signature

# DEDICATION

First of all, praise be to God who enabled me to complete this thesis.

I would like to acknowledge, to express my appreciation and deep gratitude to my adviser, Professor Dr. Zeki HASGÜR for his invaluable support, endless patience, and continuous guidance during my master's studies.

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All goals in life are not possible without the support of everyone around you, be they near or far. The support and encouragement of my beloved family was instrumental in giving me the opportunity to obtain my master's degree, so I would like to thank my beloved father, Asst. Professor Dr. Hashim, whose support me to get master's degree, as well as the support of my mother, my brother Abdullah, my sisters, my dear daughter, my beloved family who were the first to support me in reaching to what I have reached.

Obviously, this lengthy phase of master's studies would not have been so simple without the support of my peers and friends. Thank you, Bassam wazir, for being a wonderful friend and creating many memorable memories. There will be better times for future recollections.

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## ABSTRACT

# ASSESSMENT OF HYBRID RC BUILDING HAVING VARIOUS BEARING ISOLATORS

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Approaches to isolating the base have become a crucial element in enhancing quality stability during a seismic earthquake. In the present day, base detachment is routinely utilized as an essential arrangement technique for structures and frameworks in seismically active zones. The important objective of earthquake engineers is to design and build a structure in such a way that damage to the structure and its structural components during an earthquake is minimized. This thesis aims towards the dynamic analysis of a multi-story building with various parameters. For the sake of study and verification, a model of a ten-story RCC building with a symmetrical floor plan is considered. The study was conducted using SAP 2000's time-history-based software.

Several structural compositions (RC, steel, and hybrid structures), different isolators (lead rubber bearings (LRB), friction pendulum bearing, fixed, and hinged), number of bays (3, 4, and 5), and number of floors were explored in 168 models in this thesis (7, 10, 13, and 19). The response of the structure, such as time period, base shear, and story displacements, is examined and compared. The study demonstrated the effectiveness of isolation approaches for earthquake resistance. Due to the building's lowest drift story, the friction pendulum support has been favored above other types of support systems. However, although the findings demonstrated a high time period when utilizing lead rubber bearings (LRB), which demonstrates the model's capacity to endure Earthquake load, a fixed support system is not favored for seismic loads due to the larger story drifts compared to other bearing support types. The steel structure was found to be superior in terms of base shear. Combining steel and concrete for the creation of new hybrid structural systems looks to be a potential strategy for earthquake-resistant design.

**Keywords:** Base Isolation, Multi-Story Building, Base Shear, Drift, Earthquake, Rubber Supports, Seismic.

# TABLE OF CONTENTS

**Pages**

# LIST OF TABLES

**Pages**

# LIST OF FIGURES

**Pages**

# ABBREVIATIONS

| | | |
|---|---|---|
| RC | : | Reinforced Concrete |
| FEM | : | Finite Element Method |
| RCSH | : | Reinforced Concrete with Shear Wall |
| 3D | : | Three-Dimensional |
| 2D | : | Two-Dimensional |
| No. | : | Number |
| pp. | : | Page |
| Hz | : | Hertz |
| m | : | Meter |
| mm | : | Millimeters |
| Sec. | : | Second |
| SAP2000 | : | Software of Analysis Program |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| kN | : | Kilonewton |
| fć | : | (Grade of Concrete) |
| F | : | Frequency |
| Ω | : | Angle Frequency |
| T | : | Time Period |
| K | : | Structural Stiffness |
| M | : | Mass |
| C | : | Damping Coefficient |
| P | : | External Force |
| Ü | : | Absolute Acceleration |
| U | : | Relative Velocity |
| U | : | Relative Displacement |
| Θ | : | Rotation |
| $S_a$ | : | Spectral Acceleration |
| $T_n$ | : | Natural Vibration Period Values |
| $u_{max}$ | : | The Peak Deformation of a SDOF |
| $S_v$ | : | Spectral Velocity |
| $S_d$ | : | Spectral Displacement |
| S | : | Soil Factor |
| H | : | Damping Correction Factor |
| r(t) | : | Response Quantity |

| | | |
|---|---|---|
| F1 | : | Inertia force |
| Fs | : | Elastic restoring force |
| FD | : | Damping force |
| FT | : | Externally applied force |
| $r_o$ | : | Absolute Value of r(t) |

# 1. INTRODUCTION

## 1.1 PRELUDE

Earthquakes are among the most damaging natural disasters. A quake is a quick, temporary movement of the earth caused by the release of energy in a matter of seconds. Protection of civil structures, including their contents and people, is unquestionably a global concern. The goal of structural engineers is to design safer civil structures that can withstand natural disasters. Seismic isolation and energy dissipation techniques are used to strengthen earthquake resistance. Seismic isolation separates the superstructure from the ground to reduce the reaction to Earthquake load, this decreases structural earthquake forces. Most isolators improve the damping ratio. This mechanism dissipates some of the earthquake's energy, increasing the structure's and its contents' seismic performance. This novel method is a practical and economical alternative to traditional seismic strengthening. This approach is being used for a variety of civil engineering construction projects.

The present work involved a comprehensive parametric study on the effects of base isolation, using Lead Rubber Bearings (LRB), The Friction pendulum system, and Hinge base, on the nonlinear response of multi-storey buildings construction (Rc without shear wall, Rc with shear wall, Steel construction, and Hybrid construction) subjected to an earthquake. For these structures, a nonlinear time history analysis was performed under the influence of Earthquake load with different insulation methods on the reaction of the structures, with fixed and isolated bases. The structures were examined using the SAP software (2000), In the nonlinear time history analysis, the following characteristics were examined: base shear, displacement, time period, frequency, and drift ratios. These parameters were also explored in the time history analysis.

### 1.1.1 Earthquakes Load

Earthquake load are devastating events that often occur along the boundary of tectonic plates, which are portions of the earth's crust.

Every major earthquake is followed by smaller tremors known as aftershocks. During the first week following the first earthquake, they are often at their largest and most numerous. As a result, earthquake-related tragedies are more dangerous due to the possibility of extremely violent reshaking of damaged structures.

As seen in Figure 1.1, the loading of multistory buildings with equal-weight floors is further simplified as a collection of loads applied at distinct floor lines and grouped in a triangle pattern, with the top load being greater than the bottom load. Constructions that are designed to sustain these lateral forces through inelastic action must be adequately specified. These loads can range from a few percent to close to fifty percent of the building's gravity weight and are often expressed as a percentage of that weight. When a building is shaken by an earthquake, vertical loads are also generated, although these forces seldom cause the vertical load-resisting system to become overwhelmed.

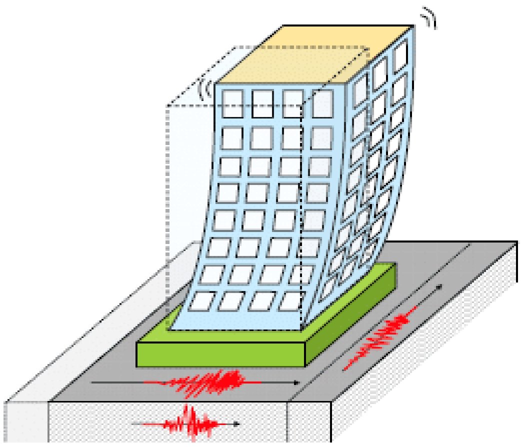


**Figure 1.1:** Seismic Loading.

## 1.2 SEISMIC METHODS OF ANALYSIS

For the determination of seismic responses, seismic analysis of the structure is required. On the basis of external action, the behavior of the structure or structural materials, and the selected structural model type, the analysis may be conducted. Depending on the sort of external stimulus and structure's behavior

The analysis can be subcategorized as:

a. Linear Static.
b. Nonlinear Static.
c. Linear Dynamic.
d. Nonlinear Dynamic.

For regular structures with restricted height, linear static analysis or an analogous static approach can be applied. Using the response spectrum approach, one may do a linear dynamic analysis. The key distinction between linear static and linear dynamic analyses is the magnitude and distribution of forces along the structure's height. Nonlinear static analysis is superior to linear static or dynamic analysis in that it permits inelastic structural behavior. The sole way for describing the real behavior of a structure during an earthquake is a nonlinear dynamic analysis. Considering the elasto-plastic deformation of the structural element, this technique is based on the direct numerical integration of differential equations of motion. This approach captures the impact of amplification owing to resonance, the variance of displacements at different levels of a frame, an increase in motion duration, and a propensity toward the regularization of motions as the level rises from bottom to top.

## 1.3 HYBRID STRUCTURES

Modern bridges and buildings often have hybrid steel-concrete construction. A composite element is produced when a steel component, such as an I-beam, is linked to a concrete component, such as a floor slab or bridge deck. The comparatively high compressive strength of the concrete in this composite T-beam counterbalances the high tensile strength of the steel. Steel-concrete composite construction is highly efficient and cost-effective due to the fact that each material is utilized to its greatest capacity. But, the main attractiveness of such a design lies in the efficient connection of the Steel to the Concrete, since it is this connection that enables the transfer of forces and confers composite elements with their unique behavior.

## 1.4 STEEL IN CONSTRUCTION

In building construction, the usage of structural steel has increased, and it is now one of the most essential input materials. Steel performs the same purpose as bones in living beings. Steel has several advantages because:

a. Provides substantial design freedom and is simple to fabricate.
b. Allows simple construction scheduling even on busy locations.
c. Facilitates speedier construction scheduling of projects.

d. Enables the repair or modification of large-span construction.
e. Suitable material for earthquake-prone areas because to its high strength, stiffness, and ductility.
f.Eco-friendly and totally recyclable when replaced.

### 1.5 VERIFICATION STUDY

The SAP2000 program was used to undertake the verification studies for RC building analysis, with data acquired from the prior literature.

### 1.6 PARAMETRIC STUDY

Several different structural compositions (reinforced concrete with and without shear wall, Steel construction, and Hybrid construction) buildings were studied to evaluate the seismic performance of these buildings under the influence of change in three parameters. These parameters are the different insulation methods (The Friction pendulum system, Lead rubber bearing, Fixed base, and Hinge base), the number of storeys (7, 10, 13 & 19 storey), and the number of bays ranging (3 to 5). The buildings were analyzed using the SAP2000 software using the time history analysis method under the influence of the EL-Centro N-S 1940 earthquake acceleration record. The results were shown the values of the base shear, time period, frequency, roof displacements and storey's drift.

### 1.7 AIM OF STUDY

This study aimed to verify the stability of multi-storey structures with different insulation methods (The Friction pendulum system, Lead rubber bearing, Fixed base, and Hinge base), and different parametric under the influence of seismic load. The case studies were based on the time history analysis of buildings, where evaluated the performance of buildings under the influence of the El Centro N-S 1940 earthquake acceleration record of the imperial valley earthquake using SAP2000 software.

### 1.8 OBJECTIVES OF STUDY

The main objectives of the present work are to comprehensively investigate the effects of several parameters on the dynamic response of a buildings, under the impacts of an earthquake. These objectives can be summarized as follows:

a. Assessment of the seismic performance of (reinforced concrete with and without shear wall, Steel construction, and Hybrid construction).
b. The models verified by comparing the results of a present work with the results available in the previous literature.
c. To study the behavior of structures with and without base isolation and know the best base isolation system for various structures.
d. To study the comparative analysis of The Friction pendulum system, Lead rubber bearing, Fixed base, and Hinge base.
e. Studying the effect of parameters base isolation, number of storeys, and number of bays on different structural composition (RC with and without shear wall, steel, and Hybrid buildings).
f.Study the effect of the presence or absence of shear walls in buildings and compare the obtained results.
g. The buildings were analyzed using the SAP2000 software using the time history analysis method under the influence of the EL-Centro N-S 1940 earthquake acceleration record.
h. The results were shown the values of the base shear, time period, roof displacements and storey's drift.

## 1.9 LIMITATIONS OF THIS STUDY

a. Different insulation methods (The Friction pendulum system, Lead rubber bearing, Fixed base, and Hinge base).
b. Different structural composition (reinforced concrete without shear wall, reinforced concrete with shear wall, Steel construction, and Hybrid construction).
c. The number of storeys (7, 10, 13, and 19) storey.
d. The number of bays ranging (3 to 5).

## 1.10 THESIS OUTLINE

The thesis includes five chapters, these are as follows:

a. First chapter dealt with a general introduction which that demonstrates the importance of studying buildings under the influence of seismic loads the objectives and scopes of the present work and a humble explanation of the contents of the thesis.

b. Second chapter is devoted to a review of past studies and investigations that focused on the effect of the base isolation systems on the seismic structural response under time history analysis in relation to the present study utilizing finite element software.
c. Chapter three shows the verification study.
d. Chapter four shows the parametric study.
e. Fifth chapter featured both the study's results and recommendations for future research.

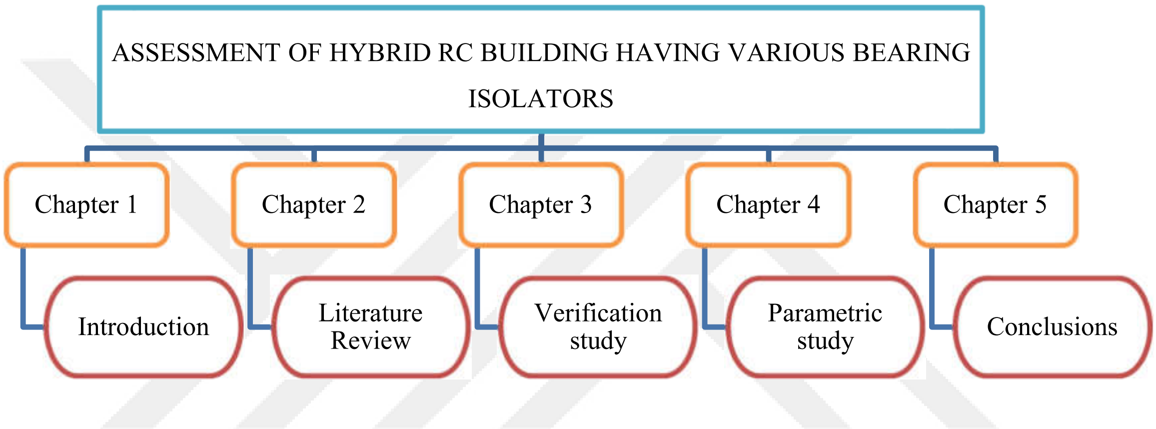



**Figure 1.2:** Layout of this Study.

# 2. LITERATURE REVIEW

## 2.1 GENERAL

This chapter presents a Base isolation, Seismic analysis, Time-History analysis, Seismic isolating systems and literature review on linear and nonlinear analysis approaches to reinforced concrete structures. The review covers a lot of research, some of which focus on the effect of base insulation systems on seismic structural response and some of which focus on the characteristics and classifications of base insulation devices. While other have focused on the effects of fill plates with base isolation on the seismic response of multi-story RC structures, including acceleration, displacement, floor drift, floor shear, and core shear.

## 2.2 BASE ISOLATION

Interposing low-horizontal-stiffness structural elements between a building's foundation and itself is central to the idea of base isolation systems, which decouple the building from the horizontal components of the ground motion and make the building's natural frequency much lower than that of its fixed base and the ground motion [1].

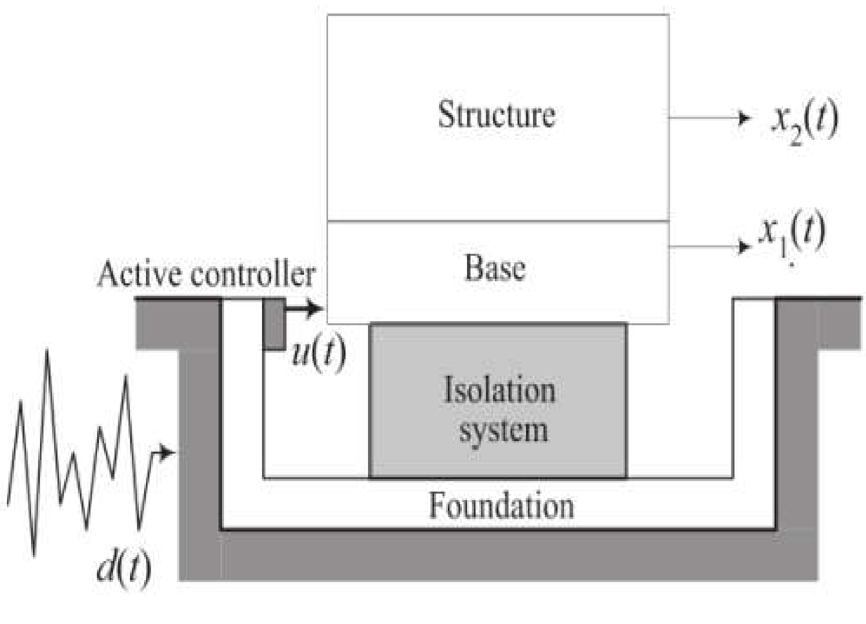



**Figure 2.1:**Building Structure with Hybrid Control System [2].

## 2.3 SEISMIC ANALYSIS

Seismic analysis is a part of structural analysis, is concerned with determining how Earthquake load would affect a structure's (or non- structure's) performance. Further subcategories are possible based on what sort of external action and structural behavior is being analyzed. linear and nonlinear Static and Dynamic Analysis are the four main types of analysis that may be used[3].

Normal buildings up to a certain height can be analyzed using linear static analysis or any analogous static method. The response spectrum method has the potential to improve linear dynamic analysis. The difference between a static and dynamic analysis may be seen in the total force applied to the building and how that force is distributed over its various levels. When comparing nonlinear static analysis to linear static analysis and linear dynamic analysis, nonlinear static analysis is preferred due to its ability to account for inelastic behavior in structures. The only reliable method for determining how a building would fare during an earthquake is a nonlinear dynamic analysis. Direct numerical integration of differential motion equations is used to account for elastic-plastic deformation of structural elements [4].

Nonlinear method is known as time series analysis. It is essential for the seismic study of structures, especially when the structural response being examined is nonlinear. To conduct such an analysis, the investigated structure must have a realistic earthquake time history. Time history analysis is a methodical examination of the time-varying dynamic response of a structure to a particular load. The seismic response of a structure under the dynamic loading of a typical earthquake is determined using time-history analysis[5].

## 2.4 TIME-HISTORY ANALYSIS

Time period in analyzing lateral loads, time period is a critical consideration. The length of time is controlled by mass and rigidity. The behavior of a structure under lateral loads may be evaluated depending on the time period [6], Figure 2.3, shown the time history of El Centro N-S earthquake acceleration.

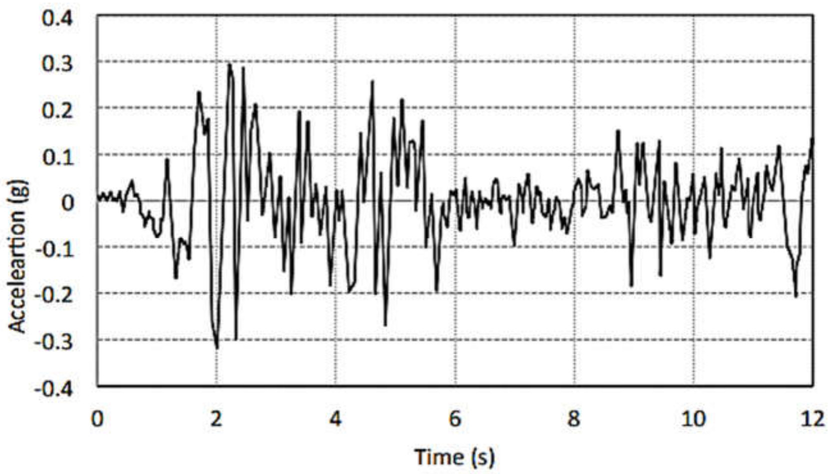



**Figure 2.2:** Time History of El Centro N-S Earthquake Acceleration [7].

As a result of an arbitrary ground displacement $X_g(t)$, the earthquake reaction is an excitation at the base. In his second law, Newton describes the conditions under which an equilibrium can be maintained [8].

$$F_1 + F_D + F_S = F_{(t)} \tag{2.1}$$

$where$:

$$F_1 = m\ddot{x}_1, \tag{2.2}$$

$$F_s = ks, \tag{2.3}$$

$$F_D = c\ddot{x}, \tag{2.4}$$

$$F_{(t)} = 0. \tag{2.5}$$

Moreover, the mass's relative displacement is denoted by x(t), whereas the mass's total (absolute) displacement is denoted by xt(t). So, can write out an expression for the condition of equilibrium as:

$$m\ddot{x}_t + c\ddot{x} + kx = 0 \tag{2.6}$$

Because the inertia form term (Ft) is proportional to the system's total motion, the damping force (FD) and elastic restoring force (Fs) are proportionate to the system's relative motion; this is taken into consideration when calculating the effective load that causes the dynamic response of this system.

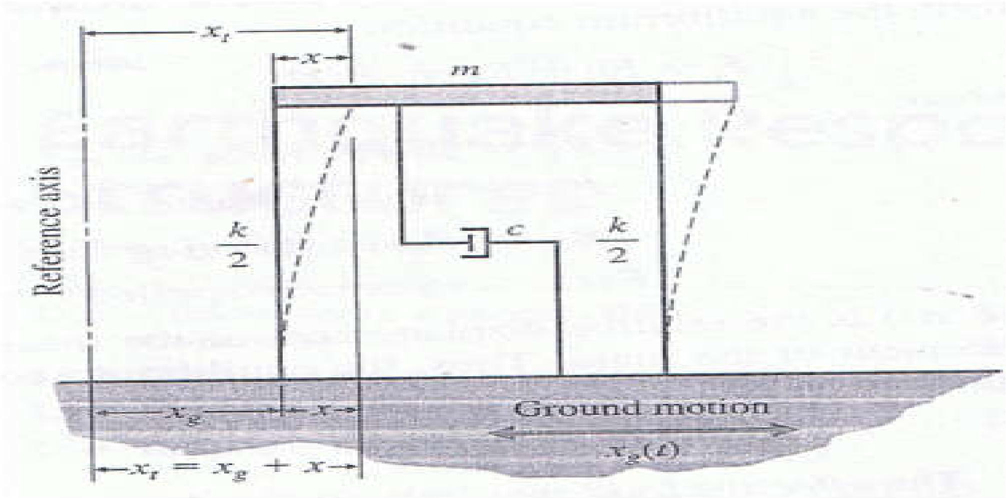



**Figure 2.3:** Rigid Base SDOF System [8].

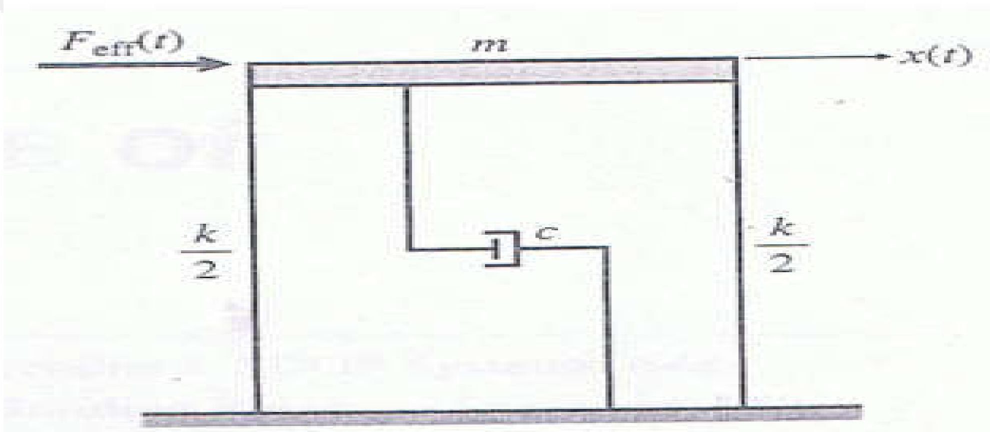



**Figure 2.4**: Description Load Owing to Horizontal Earthquake Acceleration [8].

## 2.5 STRUCTURAL CONSIDERATIONS

a. The configuration of the structure has a significant impact on its seismic reaction. High displacements or forces can be applied to structures with discontinuities in stiffness or geometry.
b. In the presence of shear walls, stiffer parts tend to carry a higher proportion of the load. However, when the impacts of greater stiffness elements, such as brick infill walls, are not taken into account in the design, unanticipated and frequently unpleasant outcomes might emerge.
c. It is necessary to ensure sufficient spacing between buildings. Codes stipulate spacing standards to guarantee that neighboring structures do not collide as a result of earthquake-induced motion.

## 2.6 SEISMIC ISOLATING SYSTEMS

To achieve the performance of the basic isolation system, the isolation system must offer the necessary lateral flexibility and damping for efficient isolation, as well as the needed service load rigidity. In this chapter, elastomeric and sliding systems are display as alternatives [9].

In the realm of structural control, base isolation system is classified as passive control. Isolators are the principal devices used to isolate components in a structural system. Figure 2.5 depicts a categorization of common isolators [9].

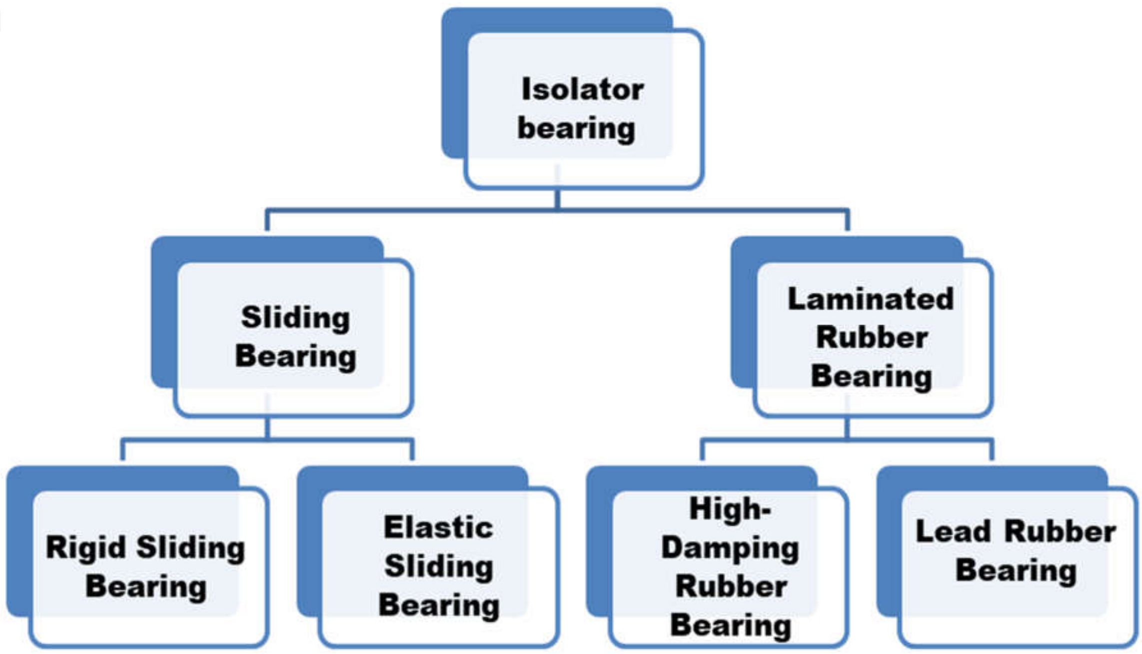



**Figure 2.5:** The Categories of Isolators [9].

### 2.6.1 Isolation System Based on Sliding

The technique of isolating a base using a sliding mechanism is the earliest and is believed to be the most straightforward. A sliding system is designed to decrease floor accelerations at the price of shear displacements between the foundation and the top structure. It is achievable by incorporating friction into geometric devices. Observations indicate that tiny brick structures cannot be efficiently separated with elastomeric isolators. Consequently, sliding systems have become more cost-effective options for earthquake-resistance solutions. The ability of sliding systems to restore a structure to its original position after a seismic event is unique to sliding systems; other types of devices may not be capable of doing so[9].

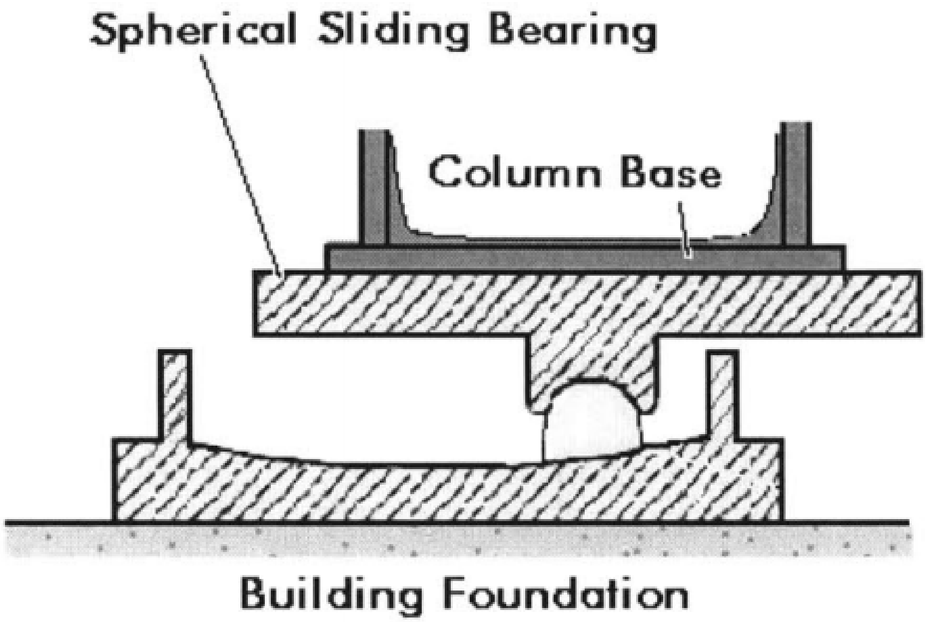



**Figure 2.6:** Schematic Diagram of Sliding System [9].

The Friction pendulum system (FPS) is a regularly used bearing based on the sliding system concept and including a pendulum-type isolator to provide a damping function through friction. On a spherical friction surface, the FPS isolator has a moveable, articulated slider. The self-lubricating composite is applied to the whole surface of the articulated slider in contact with the spherical friction surface. The other side of the slider is also coated with low-friction composite material and connected to the concave, spherical surface of stainless steel. When the slider traverses the spherical surface, the supported mass is raised, and this motion produces the system's restoring force. Under extreme conditions, such as Earthquake load, the slider slides down the concave surface, causing the supported structure to vibrate in minute arcs. By deflection (the pendulum motion) and friction (damping) on the sliders, isolators restrict the transmission of seismic forces to the structure. The radius of the concave surface's curvature will determine the system's effective stiffness and period [9].

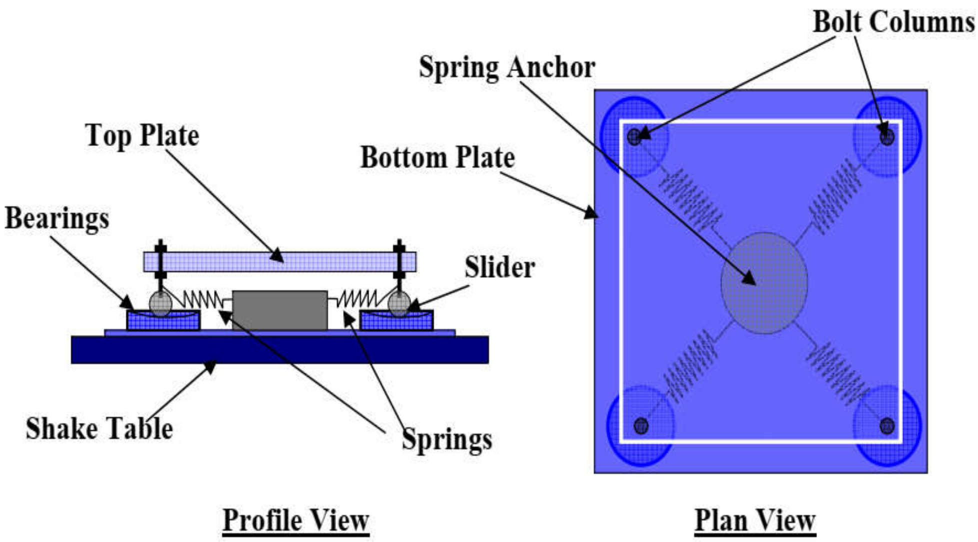



**Figure 2.7:** Design of Friction Pendulum System [10].

### 2.6.2 Laminated Rubber Bearing

Lead rubber bearing (LRB) base isolators are one of the most important earthquake protection devices. Lead rubber bearing (LRB) is one of the most -often- used isolation methods for damping and absorbing seismic energy. As illustrated in Fig. 2.8 [11], in 1975, New Zealand created lead rubber bearings, which consist of rubber layers separated by steel shims and a lead core placed into the intermediate hole.

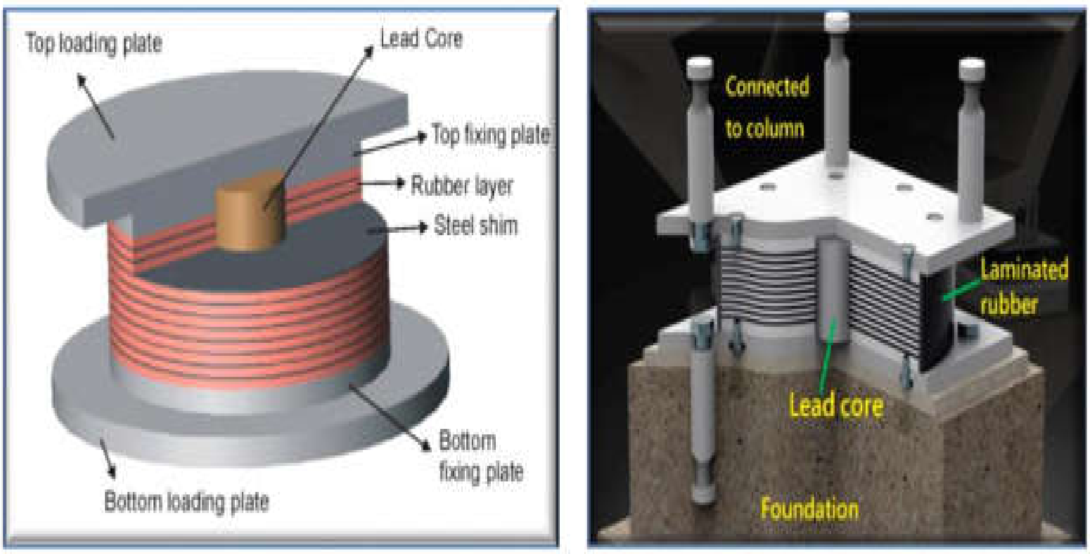



**Figure 2.8:** Lead Rubber Column's Support [1].

Here is a survey of the primary research articles and reports on the deployment of LRB and FPS as a building isolator that have been published.

Islam et al., 2011 [1] studied the behavior of seismic insulation at low- to moderate-seismic sites, in which a comprehensive analysis of the Lead Rubber Bearing (LRB), High Damping Rubber Bearing (HDRB), and friction pendulum system (FPS). Strict accounting revealed that the insulation technology was highly innovative and suitable for use in structures to withstand seismic lateral forces. It also improved safety by keeping the chassis flexible.

Chandak, 2013 [13] A parametric study of reinforced concrete (RC) structures with permanent and separated bases fitted with rubber bearings (RB) and friction isolators was conducted using the response spectrum method (FI). The design spectrum provided by Indian Standard Code IS 1893-2002 (part I) is compared with EuroCode. The major objective of this study is to compare the differences in dynamic analysis findings produced by the use of various codes for multistory RC structures with fixed and isolated base conditions. Using the computer program SAP2000, a comparative study demonstrates that the response of a building with an isolated foundation is significantly smaller than that of a structure with a fixed foundation in all cases, and that the IS code specifies higher values in all cases, with and without isolation, compared to the Eurocode.

Mkrtychev et al., 2014 [14], presented the effect of using (LRB) on the dynamic response of three different buildings of 5, 9 and 16-story heights when exposed to earthquake effects was studied. When the LRB was used instead of a fixed base, the relative displacement was reduced by 5.5 times and the absolute acceleration on the surface was lowered by 8.5 times, according to the findings.

Shaikh & Murnal, in 2015 [15] This study analyzes the fixed base and base isolator at different levels of a three-story structure. By using rubber isolators between the column and the foundation and above the beam for plinth and first floor level, seismic base isolation can lessen seismic impacts and consequently floor accelerations. In the event that the isolator's deformation capability is surpassed, the isolator may burst or buckle. Finally, the optimal placement of the insulators was examined to increase their effectiveness.

Shaikh & Kasnale, in 2015 [16] examined the effects of core insulation on reinforced concrete buildings of five and fifteen stories and compared their responses to a fixed base. A non-linear analysis of time history was performed on the two structures, and it was concluded that the isolation of the five-story building was more effective than those of the fifteen-story building. In comparison to the structure with a permanent basis, the use of base insulators increased floor displacement and decreased base shear, floor drift, and floor shear. The core insulation has been proven to reduce ground drift in five- and fifteen-story structures. In contrast, a 15-story structure improves the fundamental shear more than a 5-story one.

Sonali Anilduke, in 2015 [17] ,The fundamental concepts of base isolation are thoroughly addressed. Base Isolators regulates structural reaction by decoupling a building or structure from the horizontal component of seismic ground motion. A base-isolation system decreases a building's ductility requirements and its deformations. By conducting a nonlinear time history analysis, it was determined that base isolation increases the flexibility at the base of the structure, which aids in energy dissipation due to the horizontal component of the earthquake, resulting in a significant reduction in the superstructure's seismic demand compared to the conventional fixed base design.

Nasery et al. ,in 2015 [18] determined how highly flexible rubber bearings may be used to isolate a healthcare facility. The objective of the study was to determine how the use of this kind of insulator might improve the dynamic response of the structure in terms of internal stresses, lateral displacements, natural periods, and total construction cost. The shaft end and foundation were restrained by the rubber bearings with many plies that were approved for usage. Research was conducted into the structure's historical past, taking the seismic record into consideration. The 3D finite element study confirmed the idea that adding insulation to a building makes it much less likely to get damaged.

Swathirani et al, 2015 [19], Check the dynamic response of an eight-story C-shaped reinforced concrete structure using several types of core insulation systems, including High Damping Rubber Bearings (HDRB) and Friction Pendulum Bearings (FPB). FPB insulated buildings with FPB insulated outer columns have different stiffness from the inner columns; and finally, HDRB insulated buildings have uniform ramifications. Studying the response spectrum and the chronological history of the El Centro earthquake revealed that the use of these insulators led to a decrease in the maximum bending moment, base shear, and an increase in the normal period. In addition, HDRB high-distortion rubber bearings have been found to be a better solution than other isolators.

Saksham and Sambhav 2017 [20], made a comparison between the performance of insulated and fixed-base buildings. Response spectra and time history analyses were performed on four to twelve-story reinforced concrete structures. The results indicate that when comparing insulated core buildings with fixed base structures, the base shear is reduced and the roof is accelerated, but the natural period and offset are increased. The percentage decrease in the base shear of a 12-storey insulated base structure was found to be 22% more than that of a 4-storey insulated base building.

Nithin & Jayalekshmi, 2017 [21], Investigating the effect of incorporating several types of seismic isolation techniques on the dynamic response of a twelve-storey reinforced concrete structure. Rubber lead bearings (LRB) and friction pendulum bearings (FPB) are used as insulators. The results indicated that the use of rubber lead bearing systems and pendulum friction systems led to a reduction in building story deflections. By using (LRB) on the inner pillars and (FPB) on the outer pillars, the drift on the decks and relative displacement are greatly reduced. In addition, the results indicate a similar range in deck drifts and bedrock shear for regular and irregular structures exposed to the EL Centro, Northridge, and Loma earthquakes. For insulated core buildings, the maximum value of drift at ground level has been reported.

Santhoshkumr & Prem, 2019 [22] conducted a study on the seismic response of G+10-storey RC installations. The data was examined separately for three types of buildings: foundation structures, supporting foundations, and insulated bases. Both pre-analysis and linear time-history methodologies were used. Data shows that installing lead-rubber bearings reduces core shear and deck drift ratios and improves the seismic performance of the structure.

### 2.6.3 Employing Computer Software for Seismic Analysis

Mohan & Prabha, 2011 [23] used the program SAP 2000v12 to simulate six and eleven-story structures in India's seismic zone V, utilizing six distinct kinds of shear walls. Six distinct forms of shear walls exist: L, U, Square, Double U, I, and T, each with its own unique shape. The research is to be assessed for its efficacy in resisting lateral pressures. The findings indicated that the percentage variance of the U and T shape frame models between the two approaches was much more than the percentage variation of all other models. The Equivalent Static Method (ESM) is effective for symmetrical structures up to 25 m in height. However, for structures that are more than 25 m in height or that are asymmetrical, the Response Spectrum Method (RSM) should be employed. Shear walls with a square form were more successful, whereas shear walls with an L shape were less effective.

Hu et al., 2012 [24], This study utilizes computer applications such as STAAD, ProV8i, and ETABS to design and analyze a two-form multi-story skyscraper. The taken structure is a G+20 story, RCC and composite construction. For concrete design, time history analysis, response spectrum analysis, and p-delta analysis, the p-delta study of the columns revealed that the structure is secure and that the storey drift is within the allowable range. The base shear of an RCC structure is greater than that of a composite building, according to the Time history analysis of Etabs. Due to the tensile nature of the Steel elements utilized in the Columns, the Composite structure is inferior to the RCC structure in the event of storey drift.

Kanbir et al., 2018 [25], They studied  compares three commonly used structural analysis tools—SAP2000, 3DBASIS, and OpenSees—while modeling lead rubber bearings (LRBs) using linear and nonlinear representations. Temporal analysis is used to analyze the base displacement (BD) and top floor acceleration (TFA) responses to the Kocaeli and Chi-Chi earthquakes. OpenSees models just the temperature-dependent behavior of LRBs during nonlinear analysis, there was no statistically significant difference in the outcomes of the analyses for the three programs. When comparing the temperature-dependent behavior of LRBs to the magnitude of an earthquake, it is discovered that there may be a significant difference in how the structure interacts, which OpenSees could have shown on its own. There exists no significant difference between the analysis results obtained from SAP2000, 3DBASIS, and OpenSees in case of linear isolation systems.

Fakih et al., 2021 [26], they stuided compared the dynamic behavior of a high-rise RC structure equipped with dynamic insulators (lead rubber bearing) with that of the same building equipped with a typical shear wall system. performed using the ETABS software to determine the mode shapes, damping ratio, and normal frequencies of the two models. The results showed a significant increase in the construction period as well as a decrease in displacement, roof acceleration, inter-storey drift ratio, and core shear strength of insulated buildings compared to fixed-base buildings.

## 2.7 CONCLUDING REMARKS

Reviewing the published papers and research pertaining to the study of the seismic response of isolated base buildings based on time history analysis (nonlinear time), it was discovered that the majority of the previous work has focused on the effects of using different types of base isolators on the dynamic response of the structures. This was determined following a survey of the existing articles and studies on the seismic response of isolated base structures.

a. The Lead rubber bearing (LRB) isolation causes a decrease in roof velocity, acceleration, base shear, relative displacement, storey drift, and overturning moments, as well as an increase in the absolute roof displacements compared to the fixed base displacements.

b. The main objective of many research works was to understand the behavior of the building under the influence of seismic loads and the extent to which it maintains its safety and operability.

c. Buildings with shear walls were less susceptible to damage under the influence of seismic loads.

d. The Friction pendulum support (FPS) has been preferred type due to the lowest drift story of building when it compared with other support system.

# 3. ANALYSIS VERIFICATION MODELS

## 3.1 GENERAL

In this chapter, A reanalysis of multi-story RC structures was performed and compared other researchers' studies. Used the SAP 2000 v15 program to conduct a study of multi-story reinforced concrete structures, during which non-linear dynamic analysis was utilized in the analysis.

## 3.2 CASE STUDIES TO MODELING BY SAP 2000 SOFTWARE

The SAP 2000 finite element analysis application is used to generate 3D models and perform all analyses. The software can predict the geometric nonlinear behavior of space frames subjected to static or dynamic loads by taking into account both geometric nonlinearity and material inelasticity. In this work, the frames of a multi-story RCC structure will be subjected to a nonlinear time history analysis.

### 3.2.1 First Case Study

A model of an RC building with ten stories is utilized for validation purposes. For validation, a model of an RC building with ten stores is employed. After modeling, nonlinear time history analysis is carried. The model was introduced by (Farqaleet, 2016)[27], The building was analyzed using the time history analysis method (the building exposed to the El-Centro earthquake acceleration), 3D Model of the building shown in the Figure 3.2.

**Table 3.1:**Details of the Structure

| | |
|---|---|
| Height of the story | 3.1 m |
| Dimension of beam | 0.45 m x 0.23 m |
| Col. size | 0.5 m x 0.5 m |
| Slab thickness | 0.15 m |
| Steel grade | Fe 415 N/mm2 |
| Live Load on Typical floors | 3.5 KN/m2 |
| Dead load of slab | 3.75kN/m |
| Support conditions | Fixed |

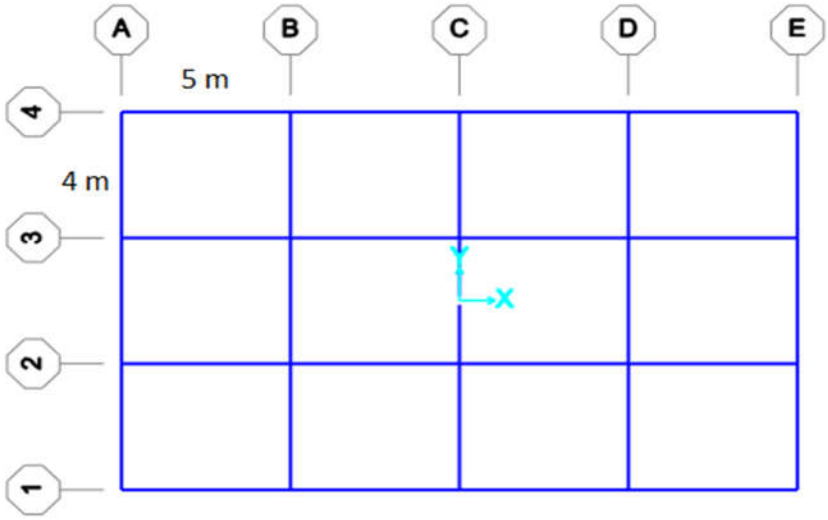



**Figure 3.1:** Plan of Model

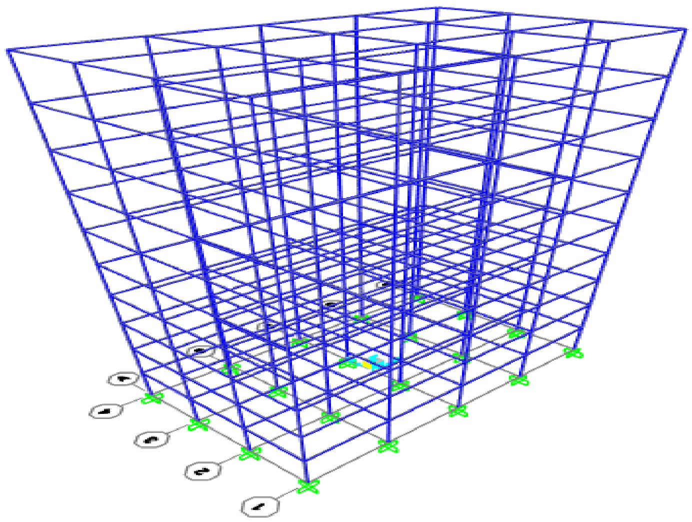


**Figure 3.2:** 3D Model of G+10 Storey Building

After modeled the building follow these steps:

a. Define the function of time history, as shown in Figure 3.3.

b. Define load cases, as shown in Figure 3.4 and Figure 3.5.

c. Run analysis, as shown in Figure 3.6**.**

d. Show the results (maximum base shear, respective period and frequency), as shown in Figure 3.7 and Figure 3.10.

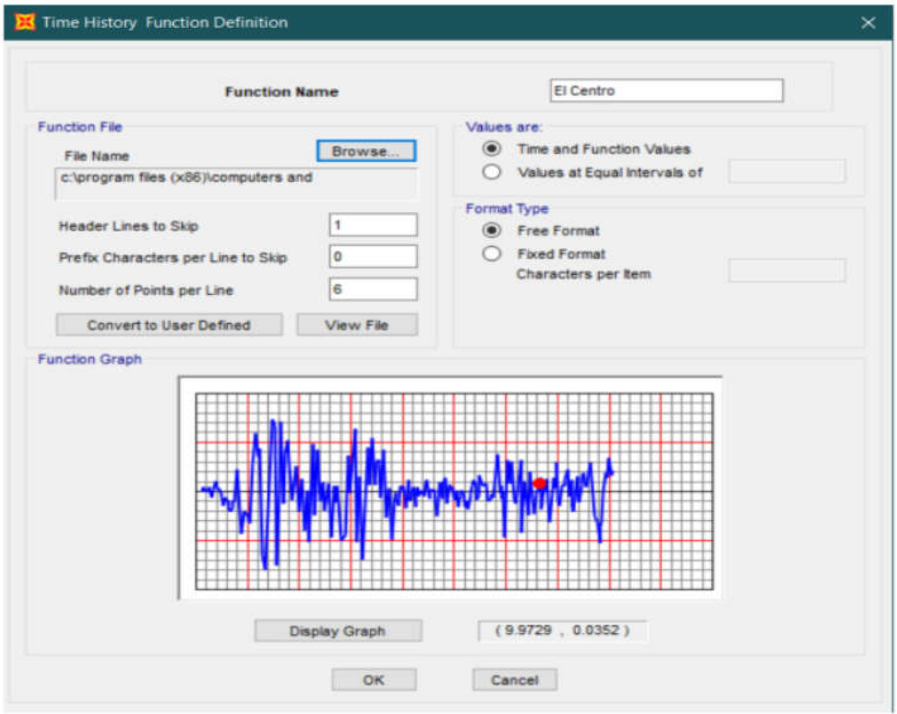



**Figure 3.3:** Time History Function Definition.

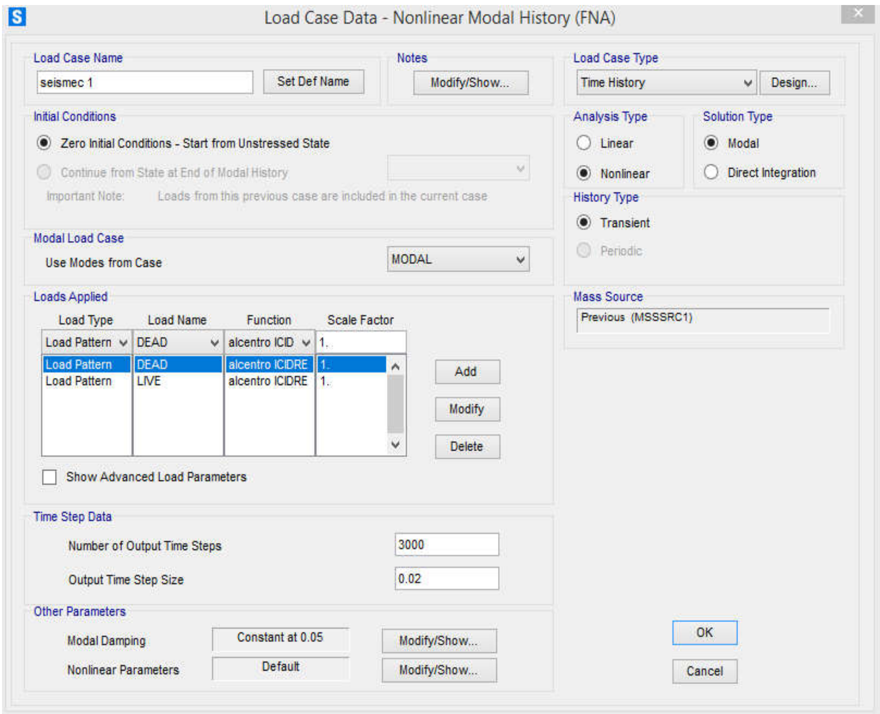



**Figure 3.4:** Define Load Cases.

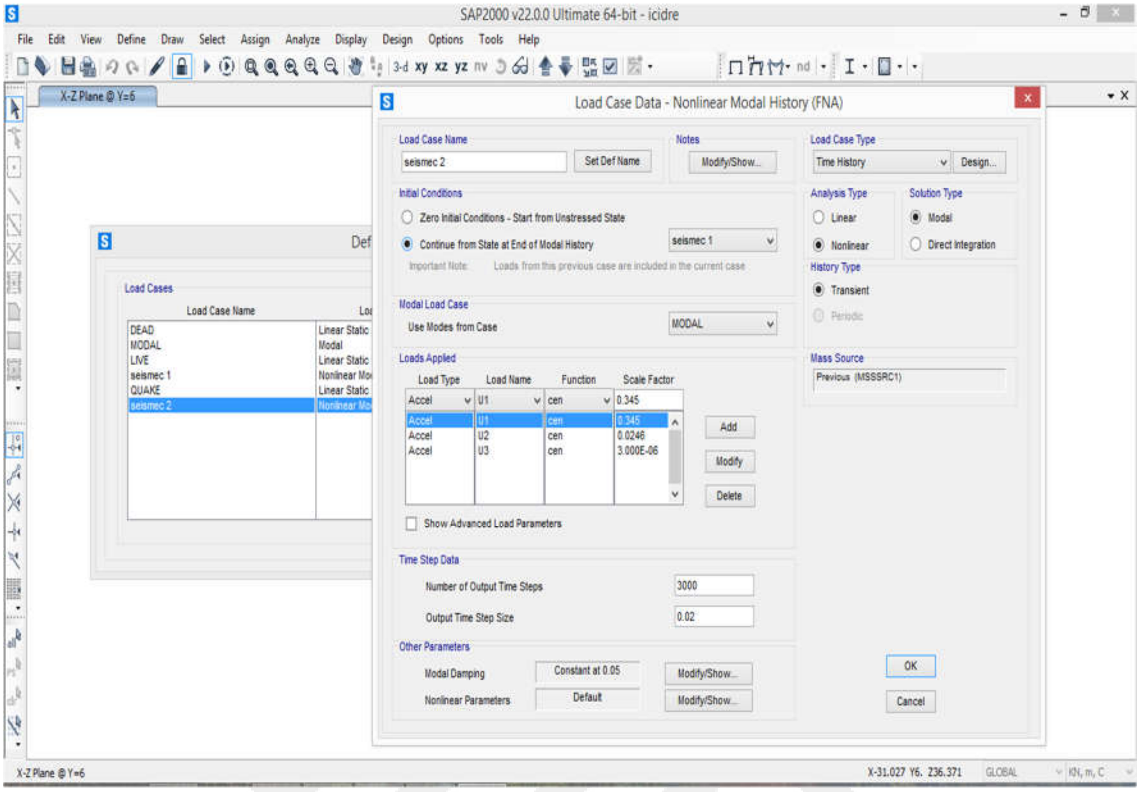


**Figure 3.5:**Define Load Cases

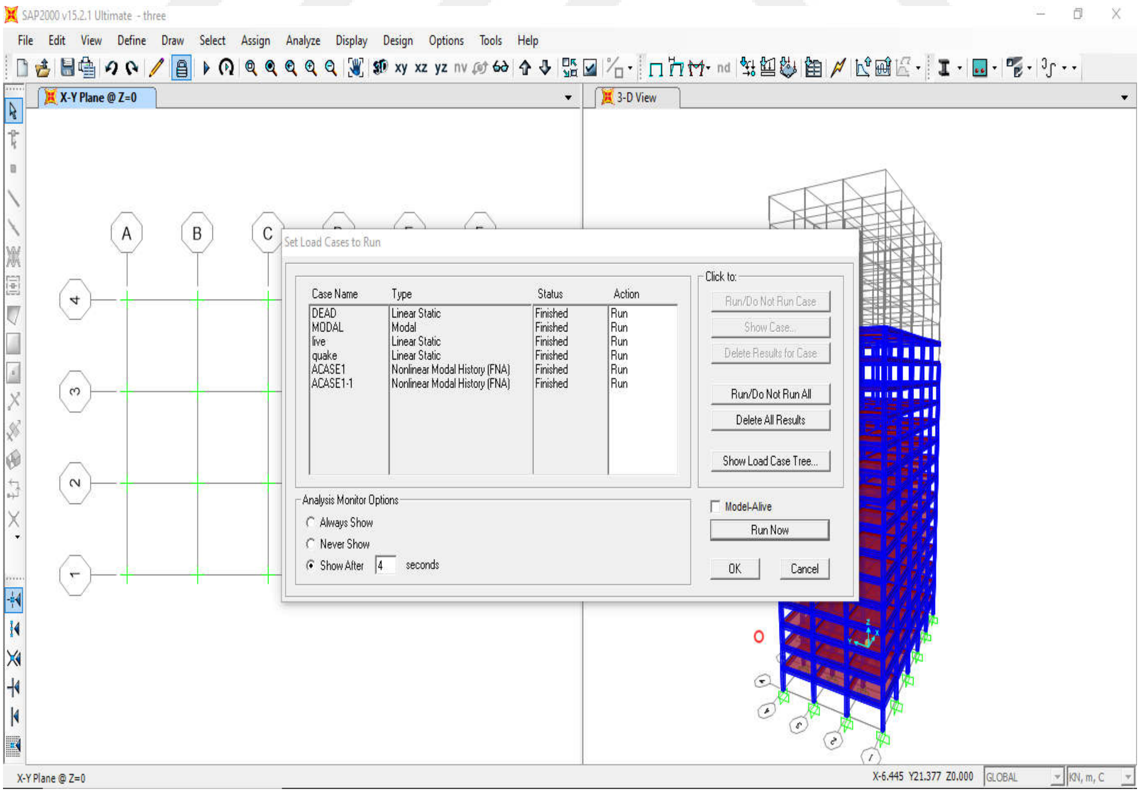


**Figure 3.6:** Run Analysis

Compared the Results between the work of (Farqaleet, 2016) and the present work:

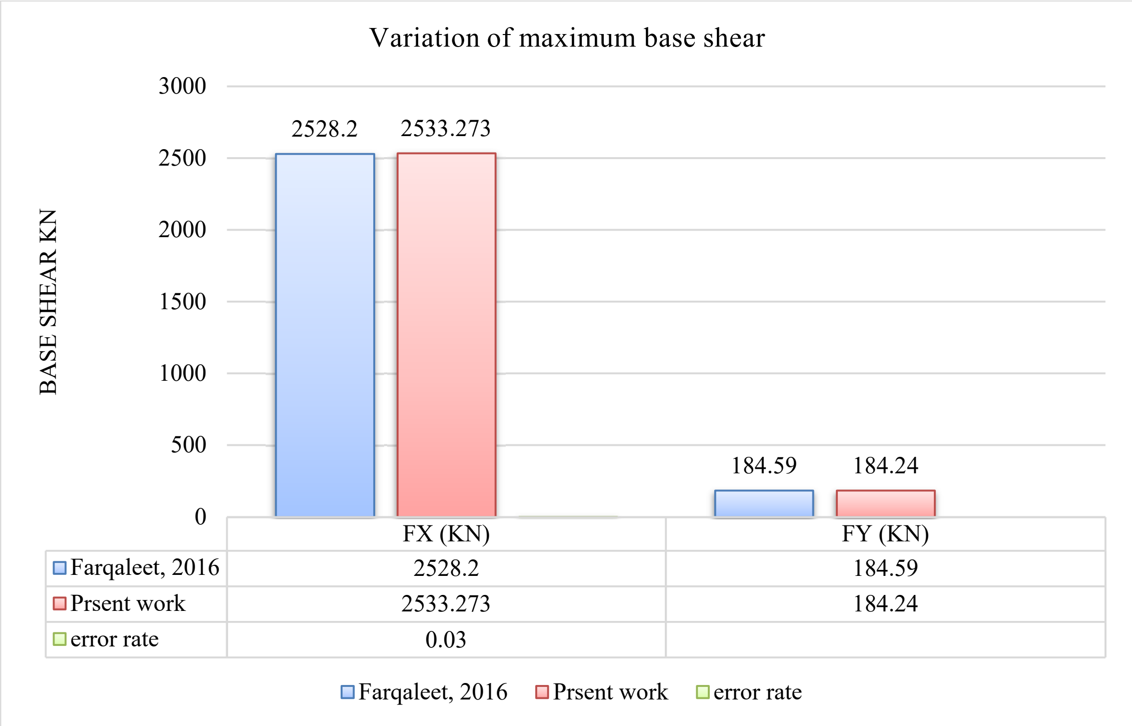



**Figure 3.7:** Changes in Maximum Base Shear.

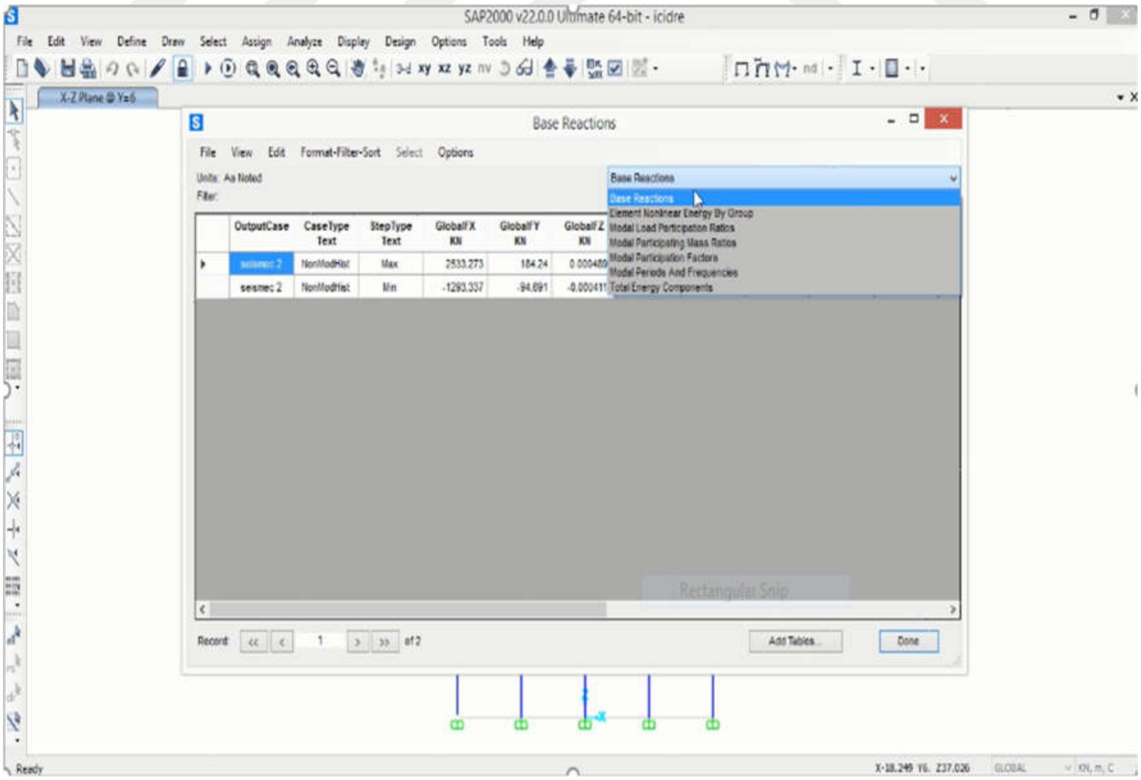



**Figure 3.8:** Variation in SAP 2000's Maximum Base Shear.

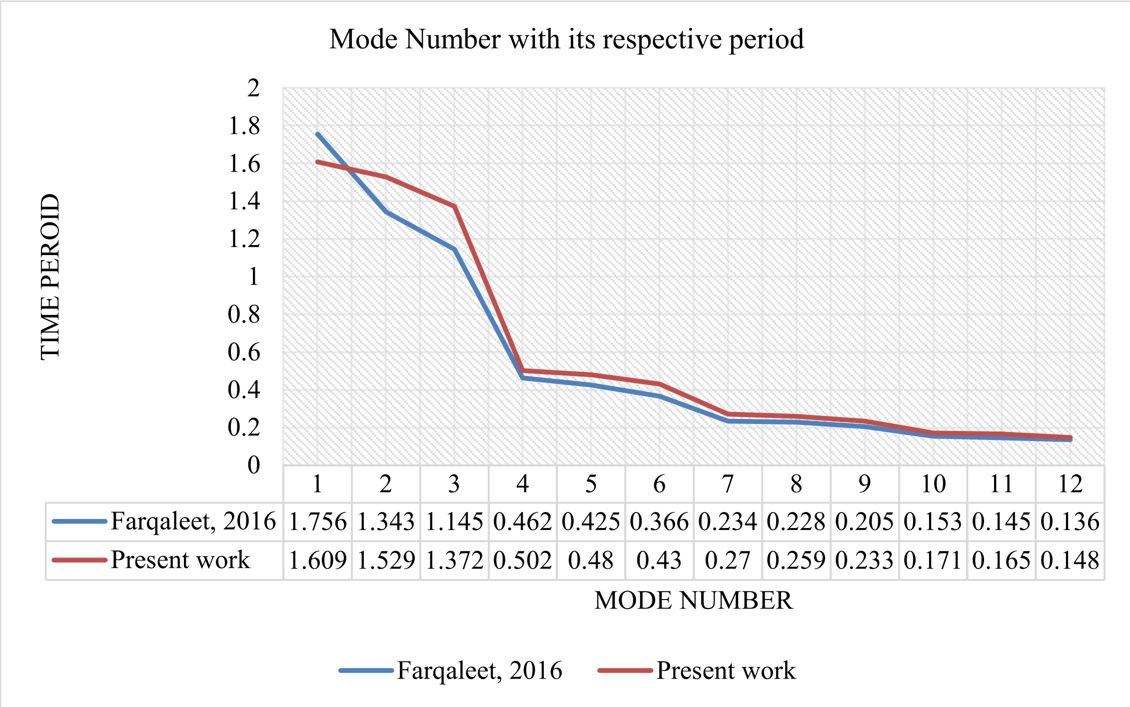



**Figure 3.9: :** Mode Number with its Respective Period

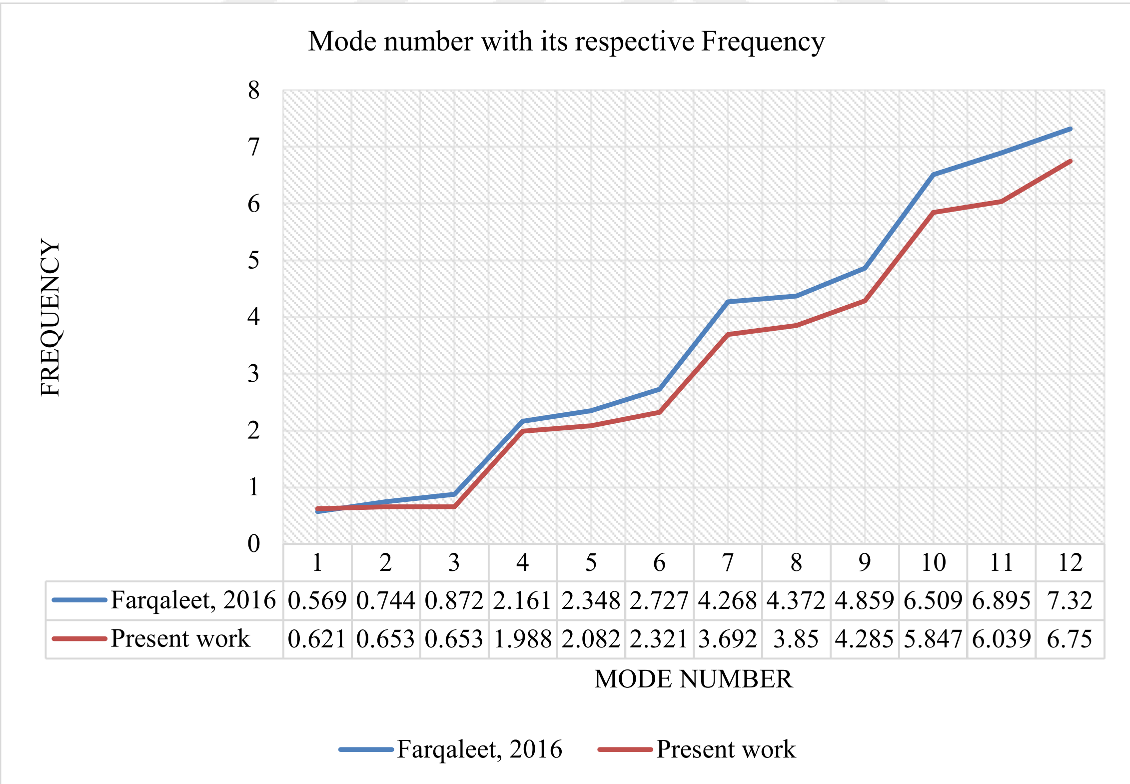
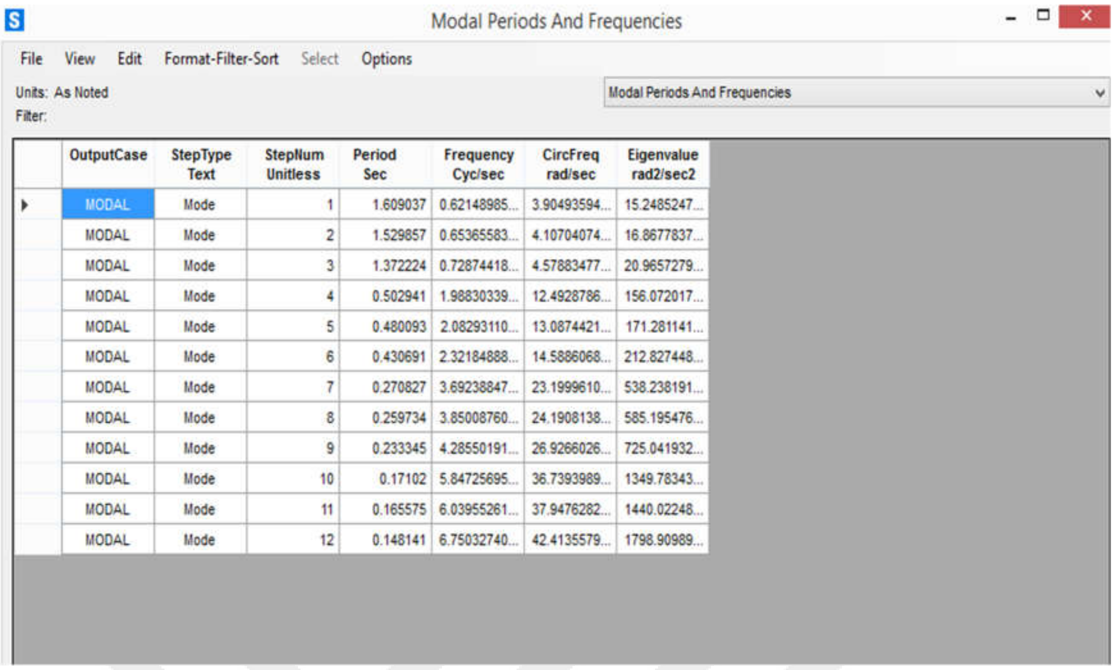



**Figure 3.10:**Mode Number with its Respective Frequency.



Modal Periods And Frequencies

File View Edit Format-Filter-Sort Select Options

Units: As Noted

Filter:

| OutputCase | StepType Text | StepNum Unitless | Period Sec | Frequency Cyc/sec | CircFreq rad/sec | Eigenvalue rad2/sec2 |
|---|---|---|---|---|---|---|
| MODAL | Mode | 1 | 1.609037 | 0.62148985... | 3.90493594... | 15.2485247... |
| MODAL | Mode | 2 | 1.529857 | 0.65365583... | 4.10704074... | 16.8677837... |
| MODAL | Mode | 3 | 1.372224 | 0.72874418... | 4.57883477... | 20.9657279... |
| MODAL | Mode | 4 | 0.502941 | 1.98830339... | 12.4928786... | 156.072017... |
| MODAL | Mode | 5 | 0.480093 | 2.08293110... | 13.0874421... | 171.281141... |
| MODAL | Mode | 6 | 0.430691 | 2.32184888... | 14.5886068... | 212.827448... |
| MODAL | Mode | 7 | 0.270827 | 3.69238847... | 23.1999610... | 538.238191... |
| MODAL | Mode | 8 | 0.259734 | 3.85008760... | 24.1908138... | 585.195476... |
| MODAL | Mode | 9 | 0.233345 | 4.28550191... | 26.9266026... | 725.041932... |
| MODAL | Mode | 10 | 0.17102 | 5.84725695... | 36.7393989... | 1349.78343... |
| MODAL | Mode | 11 | 0.165575 | 6.03955261... | 37.9476282... | 1440.02248... |
| MODAL | Mode | 12 | 0.148141 | 6.75032740... | 42.4135579... | 1798.90989... |

**Figure 3.11:** Mode Number with its Respective Period and Frequency

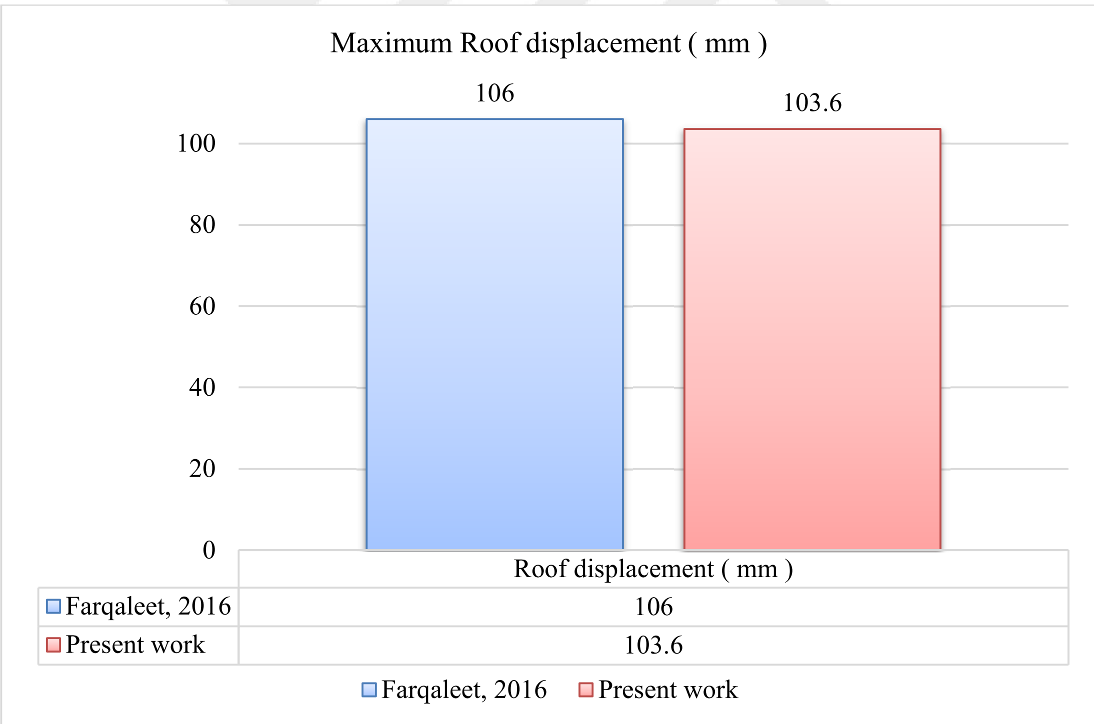



**Figure 3.12:** Maximum Roof Displacement (mm).

a. The Figure 3.12 shows that the error rate 2%.

b. So, the results are the maximum base shear (2533.273 kN) and the roof displacement (103.6 mm) for first case study.

### 3.2.2 Second Case Study

Verma et al., 2021, [28] studied a ten-story building with a 10-story RC building, non-linear analysis is performed using time history (El Centro). Figure 3.15 and Figure 3.16, shown the verified results of base shear and displacements at top tip of building values with the previous article of (Verma et al., 2021), also the Figure 3.15 and 3.16 shows that the error rate 1%.

**Table 3.2:** Details of the Structure

| | |
|---|---|
| No of storey's | 10 |
| Height of the story | 3.1 m |
| Height of the building | 31 m |
| Dimension of beam | 0.45 m x 0.23 m |
| Col. size | 0.5 m x 0.5 m |
| Thick. of slab | 0.15 m |
| Steel grade | Fe 415 N/mm2 |
| Live Load on Typical floors | 3.5 KN/m2 |
| Dead load of slab | 3.75kN/m |
| Wall load intensity | 12.19kN/m |
| Support conditions | Fixed |

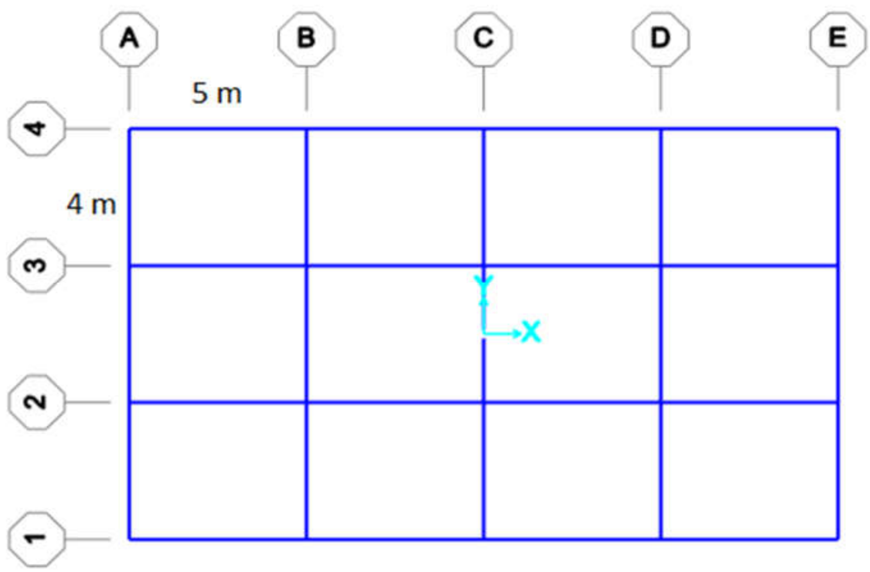



**Figure 3.13:** Plan of Model**.**

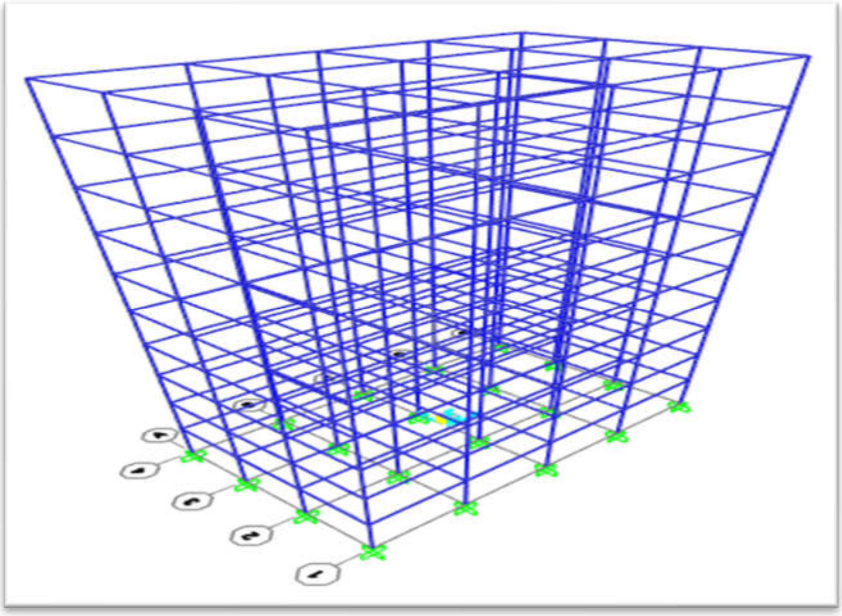


**Figure 3.14:** 3D Model of G+ 9 Storey Building.

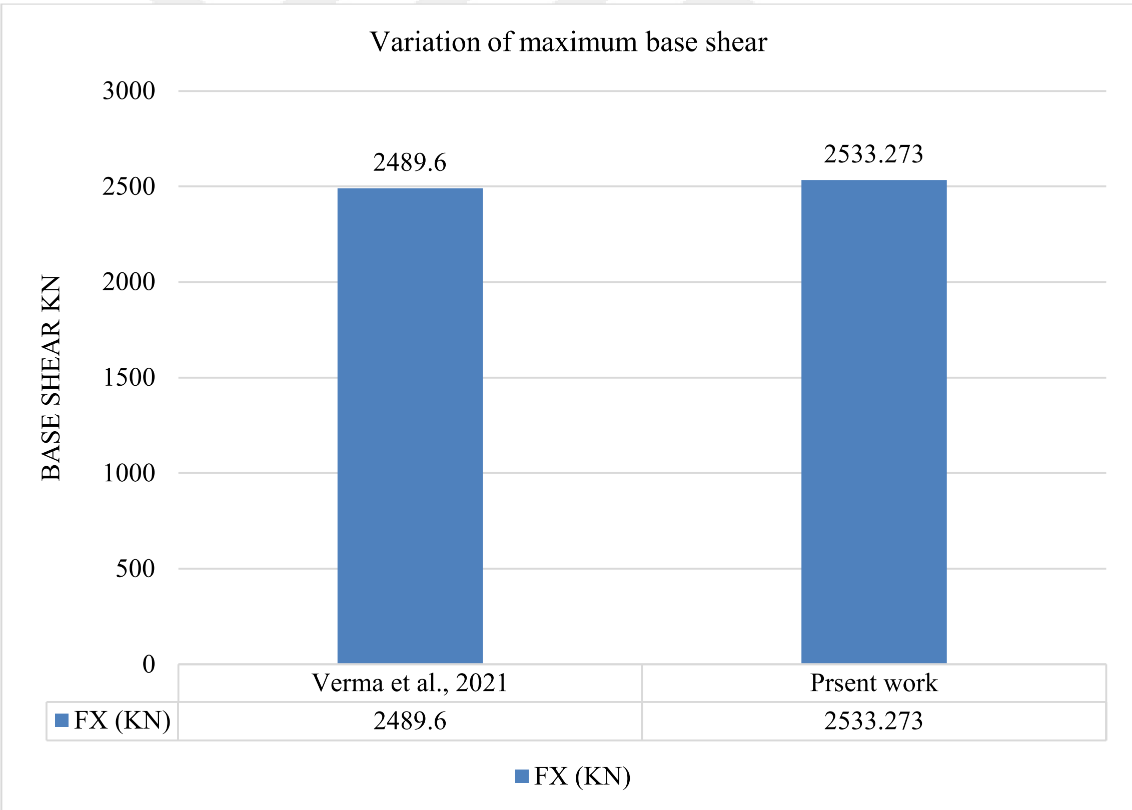



**Figure 3.15:** Variation of Maximum Base Shear**.**

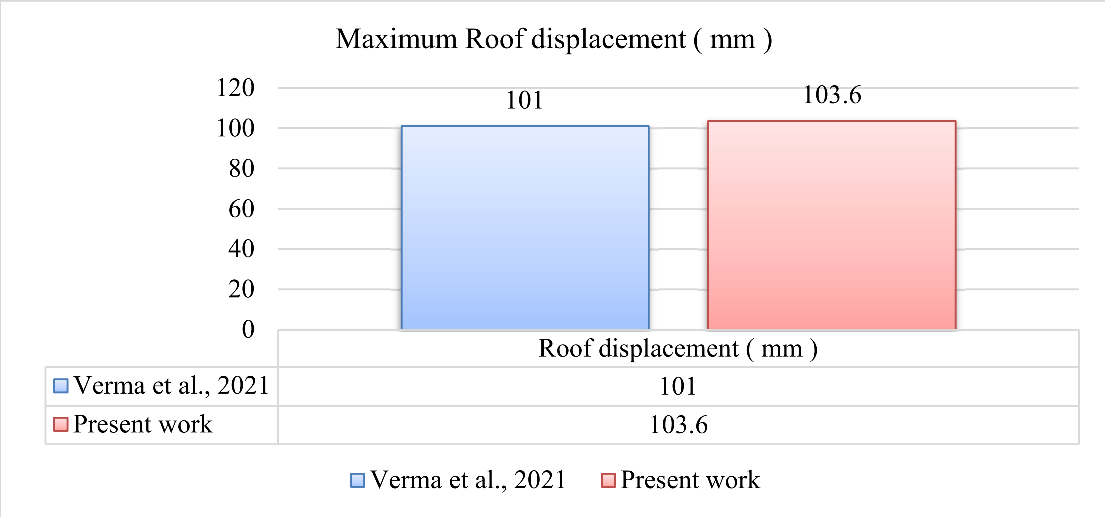



**Figure 3.16:** Maximum Roof Displacement (mm)**.**

### 3.2.3 Third Case Study

For validation, A 5-story, 10-story, 15-story, and 20-story concrete-framed building are among the selected structures. Using the commercial program SAP2000 v17 and use nonlinear time history analysis is carried with El Centro, a computer model of the building is created. Columns and Beams are represented by 3D frame components. the following parameters are used as inputs for sap2000: - - Concrete strength is 30 MPA, whereas steel strength is 415 MPA. - Floor Live Load of 3 KN/m2 - Concrete density 2500 kg/m3 - Brick wall density is 2,000 kg/m3 - Final Load of 1 KN/m2. The model was introduced by Falah ,2016 [29], Lead Rubber Base Frame Base Isolation Device are selected for each building according to the table 3.4 parameters, where Figure 3.17 show Plan of model and Figure 3.18 show 3D model of G+20 storey of building.

**Table 3.3:** Description of the Building

| | |
|---|---|
| No. of Stories | 5-10-15-20 |
| Height of the story | 3 m |
| Dimension of beam | 500 X 600 mm |
| Col. size | 500 X 500 mm |
| Thick. of slab | 200 mm |
| Live Load in Floor | 3 KN/M2 |
| Finishing Load | 1 KN/M2 |
| Density of concrete | 2500 kg/m3 |
| Density of brick wall | 2000 kg/m3 |

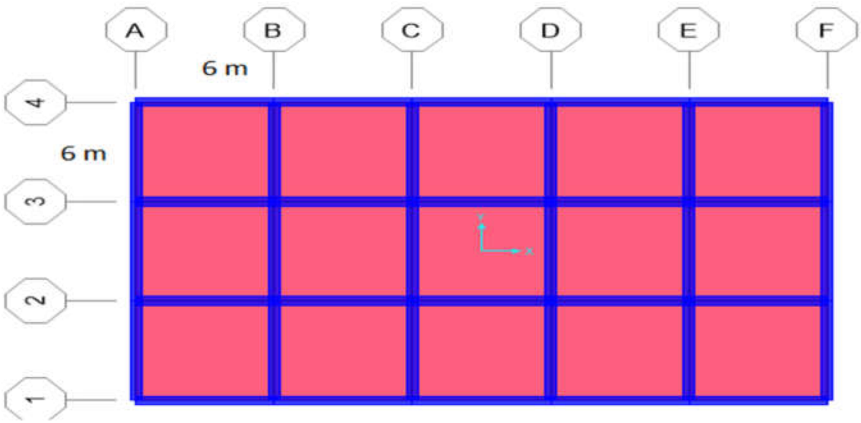



**Figure 3.17:** Plan of Model

**Table 3.4:** Base Isolation Properties

| Base isolation properties | | | | |
|---|---|---|---|---|
| Building story | 5 | 10 | 15 | 20 |
| Effective stiffness | 1715.69 | 809.96 | 495.44 | 336.49 |
| Effective damping | 0.1 | 0.1 | 0.1 | 0.1 |
| Initial stiffness | 1446.33 | 682.79 | 417.66 | 283.66 |
| Yielding strength | 52.55 | 50.24 | 47.18 | 44.06 |
| Post to initial stiffness ratio | 0.1 | 0.1 | 0.1 | 0.1 |

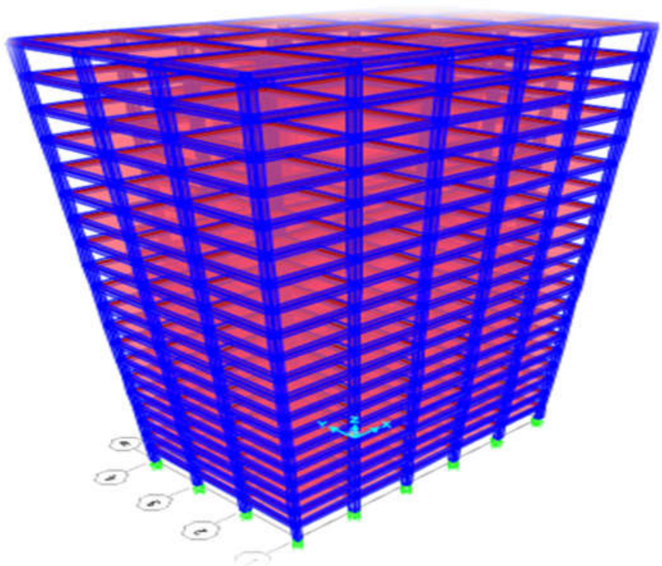


**Figure 3.18:** 3D Model of G+20 Storey

Compared the Results between the work of (Falah ,2016) and the present work:

a. Mode 1: 20 Floor

Modal Participating Mass Ratios

File View Format-Filter-Sort Select Options

Units: As Noted

Modal Participating Mass Ratios

| OutputCase Text | StepType Text | StepNum Unitless | Period Sec | UX Unitless | UY Unitless | UZ Unitless | SumUX Unitless | SumUY Unitless |
|---|---|---|---|---|---|---|---|---|
| MODAL | Mode | 1 | 7.443232 | 8.201E-17 | 0.99818 | 0 | 8.201E-17 | 0.99818 |
| MODAL | Mode | 2 | 7.396938 | 0.99871 | 8.197E-17 | 0 | 0.99871 | 0.99818 |
| MODAL | Mode | 3 | 6.482889 | 0 | 1E-19 | 0 | 0.99871 | 0.99818 |
| MODAL | Mode | 4 | 1.22709 | 0 | 0.00171 | 0 | 0.99871 | 0.99989 |
| MODAL | Mode | 5 | 1.120644 | 0.0012 | 0 | 4.72E-20 | 0.99991 | 0.99989 |
| MODAL | Mode | 6 | 0.952527 | 0 | 0 | 3.352E-19 | 0.99991 | 0.99989 |
| MODAL | Mode | 7 | 0.549284 | 0 | 0.00007945 | 2.696E-18 | 0.99991 | 0.99997 |
| MODAL | Mode | 8 | 0.528824 | 0.00006673 | 0 | 7.027E-19 | 0.99998 | 0.99997 |
| MODAL | Mode | 9 | 0.470432 | 0 | 0 | 2.693E-19 | 0.99998 | 0.99997 |
| MODAL | Mode | 10 | 0.359996 | 1.313E-20 | 0.00001506 | 3.721E-17 | 0.99998 | 0.99999 |
| MODAL | Mode | 11 | 0.34888 | 0.00001317 | 2.374E-20 | 5.663E-17 | 0.99999 | 0.99999 |
| MODAL | Mode | 12 | 0.311359 | 3.269E-20 | 5.201E-20 | 2.13E-17 | 0.99999 | 0.99999 |

Record: 1 of 12 Add Tables... Done

**Figure 3.19:** Mode number with its Respective Time period for 20 Floors with Isolation.

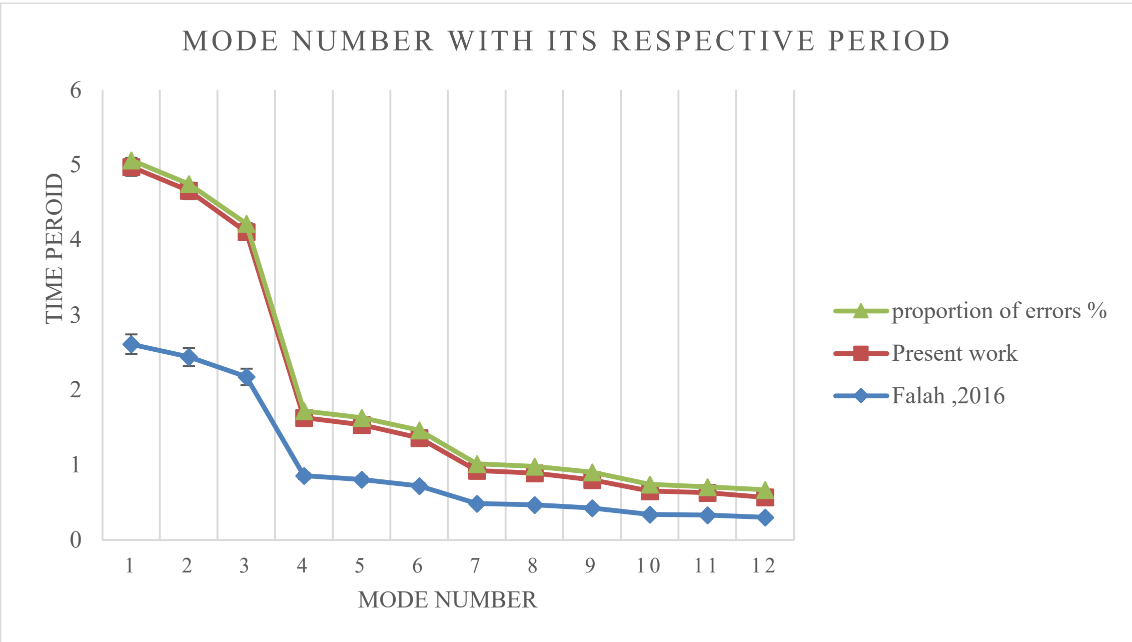



**Figure 3.20:** Compared Falah ,2016 Work with Present Work (Mode Number with its Respective Time Period)

**Table 3.5:** Compared Falah ,2016 Work with Present Work (Mode Number with its Respective Time Period for 20 Floors)

| Mode number | Without isolation | | With isolation | |
|---|---|---|---|---|
| | By Falah ,2016 [29] | Present work | By Falah ,2016 [29] | Present work |
| 1 | 2.611 | 2.464466 | 7.443 | 7.343232 |
| 2 | 2.439 | 2.217608 | 7.393 | 7.296938 |
| 3 | 2.176 | 1.932909 | 6.701 | 6.482889 |
| 4 | 0.855 | 0.772704 | 1.313 | 1.22709 |
| 5 | 0.805 | 0.732167 | 1.209 | 1.120644 |
| 6 | 0.721 | 0.640953 | 1.063 | 0.952527 |
| 7 | 0.485 | 0.437038 | 0.609 | 0.549284 |
| 8 | 0.466 | 0.423637 | 0.582 | 0.528824 |
| 9 | 0.425 | 0.377991 | 0.529 | 0.470432 |
| 10 | 0.341 | 0.308389 | 0.398 | 0.359996 |
| 11 | 0.329 | 0.29992 | 0.383 | 0.34888 |
| 12 | 0.301 | 0.267665 | 0.350 | 0.311359 |

b. Mode 2: 15 Floor

Modal Participating Mass Ratios

File View Format-Filter-Sort Select Options

Units: As Noted

Modal Participating Mass Ratios

| OutputCase Text | StepType Text | StepNum Unitless | Period Sec | UX Unitless | UY Unitless | UZ Unitless | SumUX Unitless | SumUY Unitless |
|---|---|---|---|---|---|---|---|---|
| MODAL | Mode | 1 | 5.374955 | 3.488E-17 | 0.99825 | 0 | 3.488E-17 | 0.99825 |
| MODAL | Mode | 2 | 5.34714 | 0.99864 | 3.487E-17 | 0 | 0.99864 | 0.99825 |
| MODAL | Mode | 3 | 4.69166 | 0 | 3.176E-20 | 0 | 0.99864 | 0.99825 |
| MODAL | Mode | 4 | 0.868904 | 0 | 0.00163 | 3.057E-20 | 0.99864 | 0.99988 |
| MODAL | Mode | 5 | 0.81287 | 0.00125 | 0 | 0 | 0.99989 | 0.99988 |
| MODAL | Mode | 6 | 0.706149 | 0 | 0 | 1.719E-18 | 0.99989 | 0.99988 |
| MODAL | Mode | 7 | 0.404681 | 0 | 0.00008864 | 2.259E-17 | 0.99989 | 0.99997 |
| MODAL | Mode | 8 | 0.39185 | 0.00007657 | 0 | 0 | 0.99997 | 0.99997 |
| MODAL | Mode | 9 | 0.350077 | 0 | 2.063E-19 | 1.576E-17 | 0.99997 | 0.99997 |
| MODAL | Mode | 10 | 0.266264 | 1.392E-20 | 0.00001833 | 7.002E-17 | 0.99997 | 0.99998 |
| MODAL | Mode | 11 | 0.258843 | 0.00001616 | 0 | 1.268E-17 | 0.99999 | 0.99998 |
| MODAL | Mode | 12 | 0.231434 | 1.9E-19 | 0 | 6.366E-17 | 0.99999 | 0.99998 |

**Figure 3.21:** Mode Number with its Respective Time Period for 15 Floors with Isolation.

**Table 3.6: :** Compared Falah ,2016 Work with Present Work (Mode Number with its Respective Time Period for 15 Floors)

| Mode number | Without isolation | | With isolation | |
|---|---|---|---|---|
| | By Falah ,2016 [29] | Present work | By Falah ,2016 [29] | Present work |
| 1 | 1.899 | 1.713944 | 5.356 | 5.374955 |
| 2 | 1.800 | 1.634369 | 5.323 | 5.34714 |
| 3 | 1.624 | 1.44174 | 4.829 | 4.69166 |
| 4 | 0.624 | 0.563878 | 0.937 | 0.868904 |
| 5 | 0.594 | 0.54054 | 0.880 | 0.81287 |
| 6 | 0.538 | 0.47786 | 0.788 | 0.706149 |
| 7 | 0.359 | 0.324398 | 0.449 | 0.404681 |
| 8 | 0.347 | 0.315642 | 0.431 | 0.39185 |
| 9 | 0.317 | 0.282066 | 0.393 | 0.350077 |
| 10 | 0.252 | 0.228776 | 0.294 | 0.266264 |
| 11 | 0.244 | 0.223159 | 0.284 | 0.258843 |
| 12 | 0.223 | 0.199358 | 0.259 | 0.231434 |

c. Mode 3: 10 Floor

Modal Participating Mass Ratios

File View Format-Filter-Sort Select Options

Units: As Noted

Modal Participating Mass Ratios

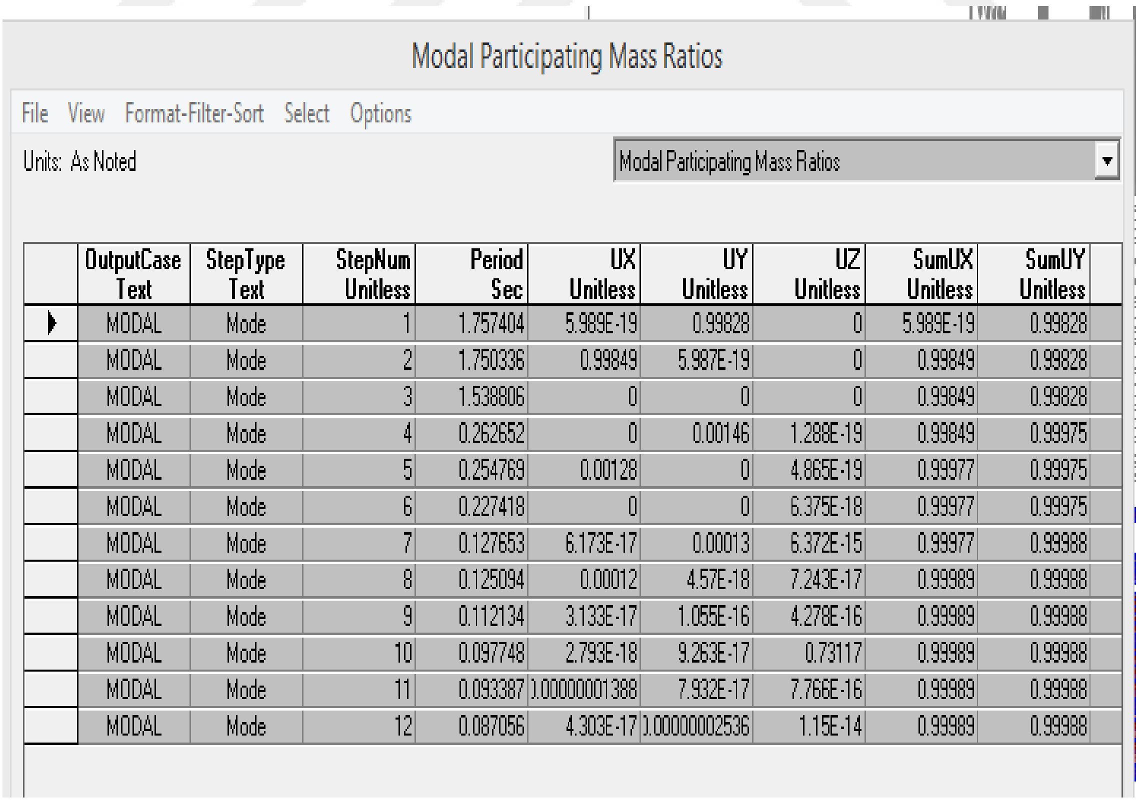
| OutputCase Text | StepType Text | StepNum Unitless | Period Sec | UX Unitless | UY Unitless | UZ Unitless | SumUX Unitless | SumUY Unitless |
|---|---|---|---|---|---|---|---|---|
| MODAL | Mode | 1 | 3.440836 | 7.559E-18 | 0.9982 | 0 | 7.559E-18 | 0.9982 |
| MODAL | Mode | 2 | 3.425329 | 0.9985 | 7.559E-18 | 0 | 0.9985 | 0.9982 |
| MODAL | Mode | 3 | 3.008755 | 0 | 0 | 0 | 0.9985 | 0.9982 |
| MODAL | Mode | 4 | 0.550087 | 0 | 0.00164 | 4.904E-20 | 0.9985 | 0.99984 |
| MODAL | Mode | 5 | 0.525266 | 0.00136 | 0 | 0 | 0.99986 | 0.99984 |
| MODAL | Mode | 6 | 0.463907 | 0 | 0 | 2.609E-17 | 0.99986 | 0.99984 |
| MODAL | Mode | 7 | 0.264302 | 6.832E-19 | 0.00011 | 7.969E-18 | 0.99986 | 0.99995 |
| MODAL | Mode | 8 | 0.257309 | 0.00009479 | 0 | 6.018E-17 | 0.99995 | 0.99995 |
| MODAL | Mode | 9 | 0.230469 | 2.094E-20 | 0 | 7.983E-18 | 0.99995 | 0.99995 |
| MODAL | Mode | 10 | 0.173579 | 5.567E-20 | 0.00002517 | 1.784E-16 | 0.99995 | 0.99997 |
| MODAL | Mode | 11 | 0.169437 | 0.00002233 | 9.962E-19 | 3.018E-16 | 0.99997 | 0.99997 |
| MODAL | Mode | 12 | 0.154518 | 1.738E-17 | 1.364E-17 | 0.79452 | 0.99997 | 0.99997 |

**Figure 3.22:** Mode Number with its Respective Time Period for 10 Floors with Isolation.

**Table 3.7:** Compared Falah ,2016 Work with Present Work (Mode Number with its Respective Time Period for 10 Floors)

| Mode number | Without isolation | | With isolation | |
|---|---|---|---|---|
| | By Falah ,2016 [29] | Present work | By Falah ,2016 [29] | Present work |
| 1 | 1.327 | 1.11506 | 3.466 | 3.440836 |
| 2 | 1.186 | 1.077128 | 3.447 | 3.425329 |
| 3 | 1.079 | 0.958441 | 3.128 | 3.008755 |
| 4 | 0.406 | 0.367099 | 0.598 | 0.550087 |
| 5 | 0.390 | 0.355707 | 0.571 | 0.525266 |
| 6 | 0.355 | 0.316594 | 0.518 | 0.463907 |
| 7 | 0.235 | 0.213335 | 0.292 | 0.264302 |
| 8 | 0.228 | 0.208526 | 0.282 | 0.257309 |
| 9 | 0.208 | 0.186219 | 0.258 | 0.230469 |
| 10 | 0.163 | 0.149556 | 0.190 | 0.173579 |
| 11 | 0.159 | 0.146603 | 0.184 | 0.169437 |
| 12 | 0.145 | 0.136446 | 0.169 | 0.154518 |

d. Mode 4: 5 Floor


Modal Participating Mass Ratios

File View Format-Filter-Sort Select Options

Units: As Noted — Modal Participating Mass Ratios

| OutputCase Text | StepType Text | StepNum Unitless | Period Sec | UX Unitless | UY Unitless | UZ Unitless | SumUX Unitless | SumUY Unitless |
|---|---|---|---|---|---|---|---|---|
| MODAL | Mode | 1 | 1.757404 | 5.989E-19 | 0.99828 | 0 | 5.989E-19 | 0.99828 |
| MODAL | Mode | 2 | 1.750336 | 0.99849 | 5.987E-19 | 0 | 0.99849 | 0.99828 |
| MODAL | Mode | 3 | 1.538806 | 0 | 0 | 0 | 0.99849 | 0.99828 |
| MODAL | Mode | 4 | 0.262652 | 0 | 0.00146 | 1.288E-19 | 0.99849 | 0.99975 |
| MODAL | Mode | 5 | 0.254769 | 0.00128 | 0 | 4.865E-19 | 0.99977 | 0.99975 |
| MODAL | Mode | 6 | 0.227418 | 0 | 0 | 6.375E-18 | 0.99977 | 0.99975 |
| MODAL | Mode | 7 | 0.127653 | 6.173E-17 | 0.00013 | 6.372E-15 | 0.99977 | 0.99988 |
| MODAL | Mode | 8 | 0.125094 | 0.00012 | 4.57E-18 | 7.243E-17 | 0.99989 | 0.99988 |
| MODAL | Mode | 9 | 0.112134 | 3.133E-17 | 1.055E-16 | 4.278E-16 | 0.99989 | 0.99988 |
| MODAL | Mode | 10 | 0.097748 | 2.793E-18 | 9.263E-17 | 0.73117 | 0.99989 | 0.99988 |
| MODAL | Mode | 11 | 0.093387 | ).00000001388 | 7.932E-17 | 7.766E-16 | 0.99989 | 0.99988 |
| MODAL | Mode | 12 | 0.087056 | 4.303E-17 | ).00000002536 | 1.15E-14 | 0.99989 | 0.99988 |

**Figure 3.23:** Mode Number with its Respective Time Period for 5 Floors with Isolation.

**Table 3. 8 :** Compared Falah ,2016 Work with Present Work (Mode Number with its Respective Time Period for 5 Floors)

| Mode number | Without isolation | | With isolation | |
|---|---|---|---|---|
| | By Falah ,2016 [29] | Present work | By Falah ,2016 [29] | Present work |
| 1 | 0.610 | 0.552363 | 1.736 | 1.757404 |
| 2 | 0.591 | 0.53889 | 1.726 | 1.750336 |
| 3 | 0.539 | 0.48062 | 1.567 | 1.538806 |
| 4 | 0.197 | 0.18011 | 0.286 | 0.262652 |
| 5 | 0.191 | 0.176354 | 0.276 | 0.254769 |
| 6 | 0.174 | 0.156972 | 0.253 | 0.227418 |
| 7 | 0.112 | 0.104928 | 0.139 | 0.127653 |
| 8 | 0.110 | 0.103417 | 0.135 | 0.125094 |
| 9 | 0.100 | 0.091773 | 0.124 | 0.112134 |
| 10 | 0.078 | 0.080832 | 0.088 | 0.097748 |
| 11 | 0.077 | 0.078321 | 0.087 | 0.093387 |
| 12 | 0.076 | 0.07492 | 0.080 | 0.087056 |

### 3.2.4 Fourth Case Study

(Nitya M & Arathi S, 2013) [30], They examined a G+6-story reinforced concrete moment-resisting frame with and without base isolation. The analysis is performed using the SAP 2000 v14 software. For the 1940 El Centro earthquake, a Time-history analysis is conducted. The following are the specifications for an irregular G+6-story RC building.

**Table 3.9:** Description of the Building

| | |
|---|---|
| No. of Stories | 6 |
| Height of the story | 3 m |
| Dimension of beam | 0.5 m x 0.23 m |
| Col.  size | 0.3 m x 0.5 m |
| Thick. of slab | 0.16 m |
| Steel type | Fe 415 N/mm2 |

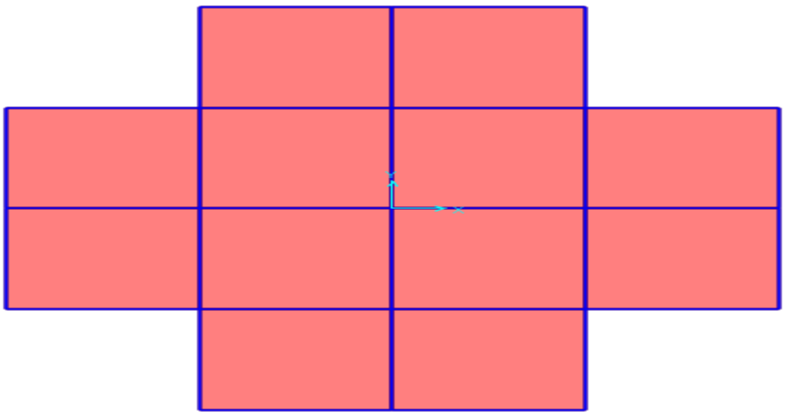


**Figure 3.24:** Plan of the Model**.**

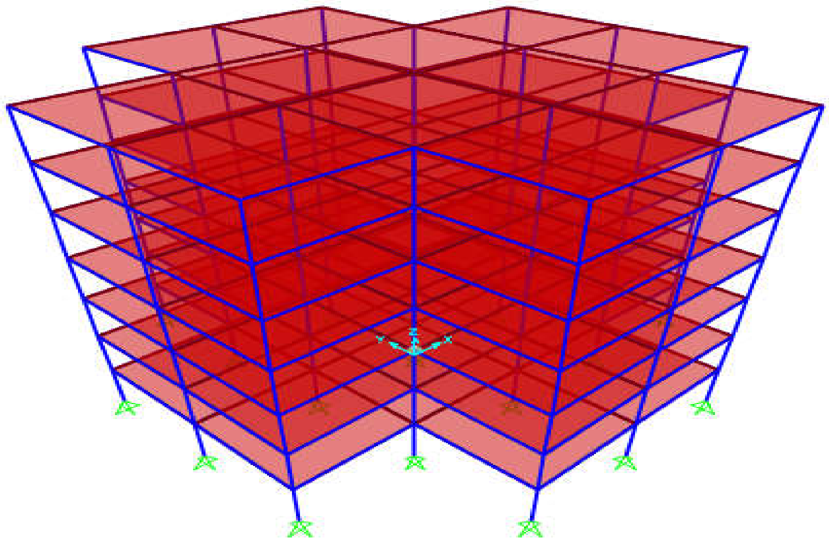


**Figure 3.25:** 3D View of the Model.

**Table 3.10:** Material Properties

| Material Property | Values |
|---|---|
| Density of concrete | 25 kN/m3 |
| Grade of concrete | 30 MPa |
| Grade of reinforcing steel | Fe 415 MPa |
| Modulus of Elasticity of concrete | 27386 MPa |
| Modulus of Elasticity of steel | 2×105 MPa |

**Table 3.11:** Properties of Rubber Isolators

| | U1 | U2 | U3 |
|---|---|---|---|
| Linear effective stiffness (kN/m) | 1500000 | 800 | 800 |
| Nonlinear stiffness (kN/m) | | 2500 | 2500 |
| Yield Strength (kN) | | 80 | 80 |
| Post yield stiffness | | 0.1 | 0.1 |

**Table 3.12:** Properties of Friction Isolators

| | U1 | U2 | U3 |
|---|---|---|---|
| Linear effective stiffness (kN/m) | 15000000 | 750 | 750 |
| Non-linear stiffness (kN/m) | | 15000 | 15000 |
| Friction coefficient, slow | | 0.03 | 0.03 |
| Friction coefficient, fast | | 0.05 | 0.05 |
| Rate parameter | | 40 | 40 |
| Radius of Sliding surface | | 2.23 | 2.23 |

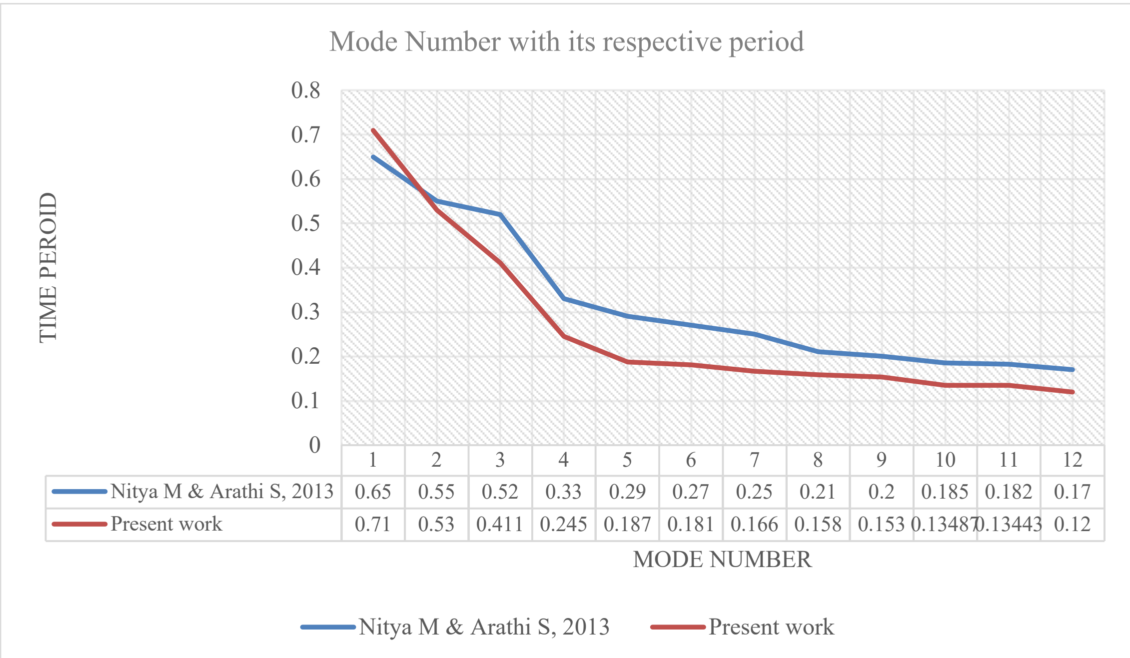



**Figure 3.26:** Comparison of Modal Analysis Results for Fixed Buildings

**Table 3.13:** Comparison of Modal Analysis Results for Fixed and Isolated Buildings

| Time Period (s) | | | | | | |
|---|---|---|---|---|---|---|
| Number | Fixed | | Rubber | | Friction | |
| | Nitya,2013 | Present work | Nitya,2013 | Present work | Nitya,2013 | Present work |
| 1 | 0.653 | 0.71 | 1.354 | 1.349 | 1.357 | 1.361 |
| 2 | 0.552 | 0.53 | 1.252 | 1.248 | 1.246 | 1.251 |
| 3 | 0.524 | 0.411 | 1.234 | 1.229 | 1.211 | 1.214 |
| 4 | 0.337 | 0.245 | 0.345 | 0.348 | 0.344 | 0.339 |
| 5 | 0.293 | 0.187 | 0.304 | 0.299 | 0.304 | 0.299 |
| 6 | 0.273 | 0.181 | 0.292 | 0.289 | 0.291 | 0.285 |
| 7 | 0.258 | 0.166 | 0.276 | 0.271 | 0.276 | 0.274 |
| 8 | 0.215 | 0.158 | 0.261 | 0.257 | 0.261 | 0.260 |
| 9 | 0.202 | 0.153 | 0.256 | 0.251 | 0.256 | 0.251 |
| 10 | 0.185 | 0.134868 | 0.252 | 0.248 | 0.251 | 0.248 |
| 11 | 0.182 | 0.134429 | 0.203 | 0.199 | 0.202 | 0.199 |
| 12 | 0.176 | 0.12 | 0.182 | 0.172 | 0.182 | 0.178 |

## 3.3 CONCLUDING REMARK

a. After modeled and analyzed two models, the results were based on the base shear, displacements, and Time period values. All results obtained in the present work were close to those of previous literatures.

b. For example, in the first study case, the maximum base shear value and maximum displacements in the present work were 2533.273 kN and 103.6 mm, respectively, while their values were 2528.2 kN and 106 mm according to the results of Farqaleet, 2016.

c. The verification modeling method was beneficial because it provided an understanding of the findings of earlier studies, improved the user's proficiency with SAP 2000, and increased confidence in the findings of the current study.

# 4. PARAMTETRIC STUDY MODELLING OF RC AND HYBRID BUILDINGS

## 4.1 GENERAL

This chapter deals with the use of finite element analysis to study the response of buildings with different dimensions, different insulation methods (The Friction pendulum system, Lead rubber bearing, Fixed base, and Hinge base) and different structural composition (RC, steel, and Hybrid buildings). The effect of Earthquake load on these buildings varies when subjected to seismic loads. These buildings have a lot of weaknesses that need to be discovered and then developed properly. The seismic performance of the buildings was examined to obtain results that give the possibility of appropriate analysis and design of these buildings. Therefore, different insulation methods were used in addition to the construction of shear walls for these buildings to reduce seismic forces. All the obtained results were compared with different foundations of insulation methods, in addition to the presence and absence of shear walls, and compared concrete buildings with steel buildings, in addition to comparing them with hybrid buildings (25 % concrete + 75 % steel). All buildings were analyzed using SAP2000 software using the time-history analysis method under the influence of the EL-Centro N-S 1940 seismic acceleration record. The results showed the values of basic shear, time history, Frequency, roof displacements and floor drift.

## 4.2 MODEL DESCRIPTION AND STUDY METHODOLOGY

Several buildings were studied to evaluate the seismic performance of these buildings under the influence of change in four parameters. These parameters are the various isolators (Lead Rubber Bearings (LRB), Friction Pendulum Bearing, Fixed, and Hinge), the number of storeys (7, 10, 13, and 19 storey), the span length (6) m, and the number of bays (3, 4, and 5), as shown in Figure 4.1, The results were obtained by modeling 128 cases in the SAP 2000 program and these results had been shown in 80 Figures. The analysis was carried out for concrete structures in the presence and absence of shear walls and steel structures in addition to hybrid structures (25% concrete + 75% Steel) The results of each case were shown in 80 Figures. These results depend on the parameters, where the effect of the insulation methods (The Friction pendulum system, Lead rubber bearing, Fixed base, and Hinge base) and the storey number appears in 64 Figures, and The effect of different construction systems with isolation methods is shown in 16 Figures, while the effect of the span length and number of bays are shown in several cases where one of them is constant and the other is variable in order to show the effect of the variable parameter, as shown in Figure 4.2.

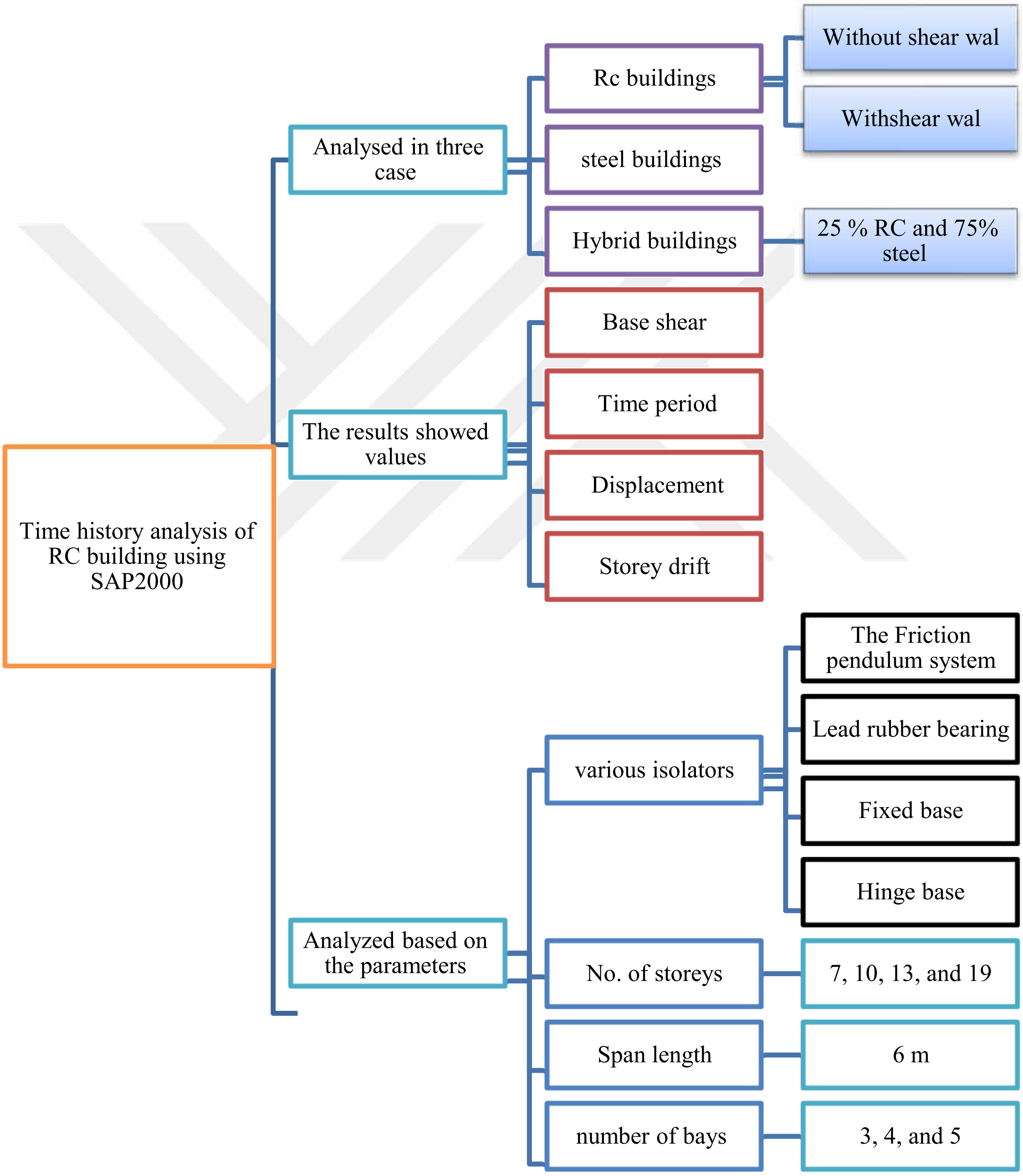



**Figure 4.1:** Time History Analysis of RC Building using SAP2000.

**Table 4.1:** Details of the Structure.

| | |
|---|---|
| Type of Frame | Special moment resisting frame |
| No of storey's | 7, 10, 13, 19 |
| Storey height | 3.1 m |
| Slab thickness | 150mm |
| Wall thickness | 230mm |
| Wall masonry | Brick |
| Steel grade | S420 |
| Rebar grade | HYSD 415 |
| Concrete grade | C30 |
| Support conditions | Fixed, Base isolated |

**Table 4.2:** Section Details**.**

<table>
<tr><th>Structure</th><th colspan="2">Column</th><th>Beam</th></tr>
<tr><td>RCC</td><td colspan="2">500 * 500 mm</td><td>300*450mm</td></tr>
<tr><td rowspan="5">Steel</td><td colspan="2">(Built up I section)</td><td rowspan="5">ISMB550</td></tr>
<tr><td>Total Depth</td><td>900mm</td></tr>
<tr><td>Flange Width</td><td>500mm</td></tr>
<tr><td>Flange thickness</td><td>60mm</td></tr>
<tr><td>Web thickness</td><td>50mm</td></tr>
<tr><td>Composite</td><td colspan="2">600 * 600 mm (ISMB400)</td><td>ISMB350</td></tr>
</table>

**Table 4.3:** Properties of Lead Rubber Bearing Isolator**.**

| | |
|---|---|
| U1 Linear Effective Stiffness | 1500000kN/m |
| U2 and U3 Linear Effective Stiffness | 800kN/m |
| U2 and U3 Non-Linear Stiffness | 250kN/m |
| U2 and U3 Yield strength | 80kN |
| U2 and U3 Post Yield stiffness ratio | 0.1 |
| PYSR | 0.1 |

**Table 4.4:** Properties of Friction Pendulum System Isolator.

| | |
|---|---|
| U1 Linear Effective Stiffness | 1500000kN/m |
| U1 Nonlinear Effective Stiffness | 1500000kN/m |
| U2 and U3 Linear Effective Stiffness | 750kM/m |
| U2 and U3 Non-Linear Stiffness | 1500kN/m |
| U2 and U3 Friction Coefficient, Slow | 0.03 |
| U2 and U3 Friction Coefficient, Fast | 0.05 |
| U2 and U3 Rate Parameter | 40 |
| U2 Radius of Sliding Surface | 2.23 |

The methods outlined below:

a. Review the many studies of the researchers that were compiled from earlier study.
b. Selected and modeled the various multistory structures.
c. Performing dynamic analysis on a given building model and plotting the findings of the study in the form of graphs.
d. Modeled the type of support as a Friction pendulum system, a Lead rubber bearing, a Fixed base, and a Hinge base.
e. The influence of soil structure interaction was disregarded.

f. A three-dimensional structure exposed to seismic forces. In SAP 2000, storey displacements, time period, frequency, and base shear are analyzed for buildings with seven to nineteen stories using the time history approach with and without shear walls.

## 4.3 MODELING RESULTS OF BUILDINGS RC THAT HAVING VARIOUS BEARING ISOLATERS

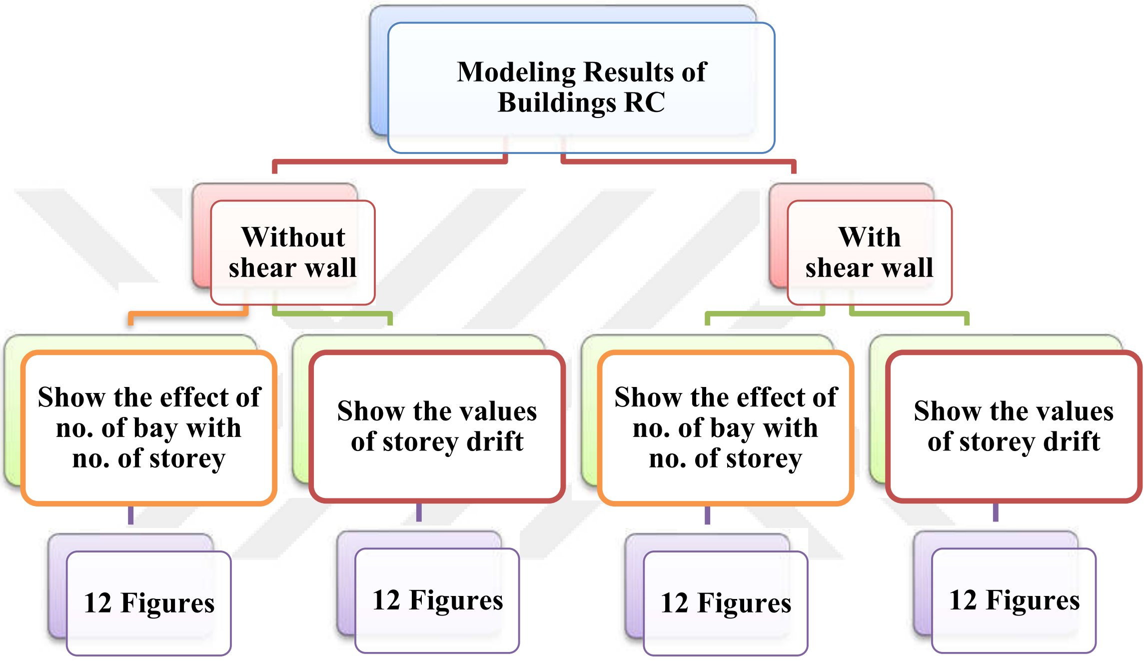



**Figure 4.2 :**Modeling Results of Time History Analysis of Buildings**.**

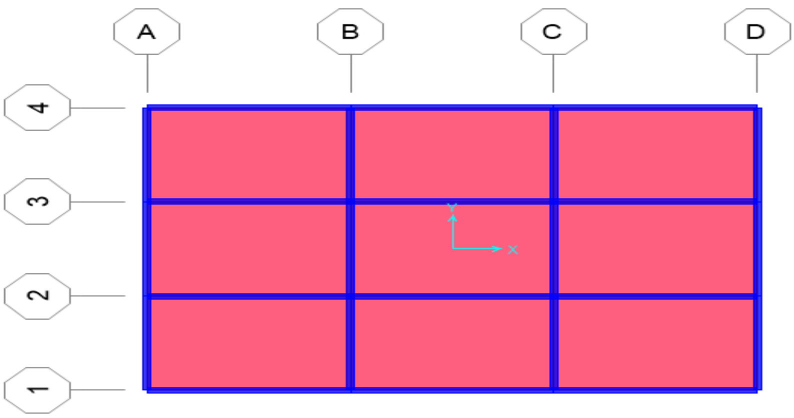



**Figure 4.3** :Plan of the Building for First Model.

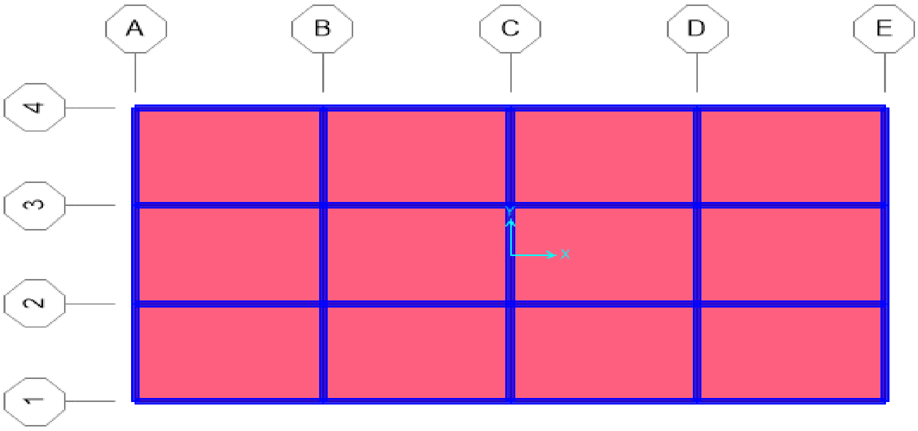



**Figure 4.4:** Plan of Building for Second Model.

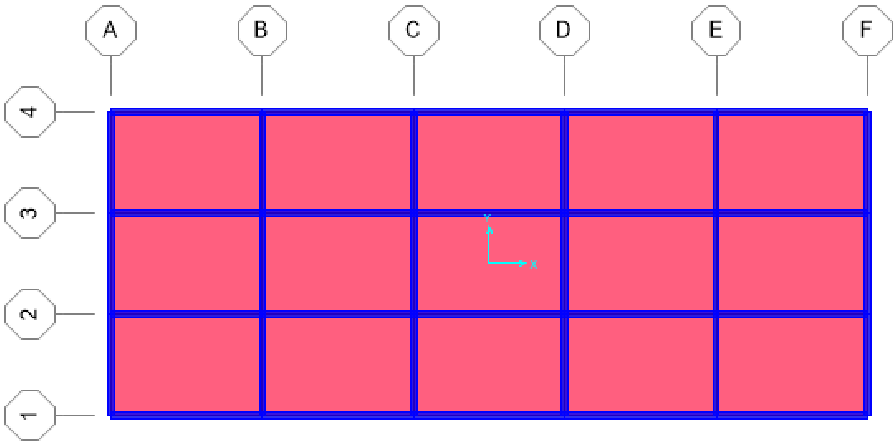



**Figure 4.5:** Plan of Building for Third Model.

### 4.3.1 Modeling Results of Buildings RC Without Shear Wall

#### 4.3.1.1 Modeling results based on the no. of storeys and no. of bay without shear wall

The value of the base shear, Time period, frequency, and displacements increased or decreased with various isolators (The Friction pendulum system, Lead rubber bearing, and Hinge base) compared to fixed buildings, as shown below:

a. As shown in Figure 4.6, The value of base shear increased compared Fixed buildings with Lead rubber bearing and Hinge base by (22%, & 12%) respectively, While the Friction pendulum system decreased by (72%) compared Fixed buildings, when the No. of storeys were 7. while when the No. of storeys 19 the value of base shear increased compared Fixed buildings with Lead rubber bearing and Hinge base by

(40%, & 6%) respectively, While the Friction pendulum system decreased by (48%) compared Fixed buildings.

b. As shown in Figure 4.7, the value of time period increased compared Fixed buildings with (Lead rubber bearing, the Friction pendulum system, and Hinge base) by (148%, 52%, & 25%) respectively, when the No. of storeys were 7. while when the No. of storeys 19 the value of time period increased compared Fixed buildings with (Lead rubber bearing, the Friction pendulum system, and Hinge base) by (60%, 15%, & 8%) respectively.
c. As shown in Figure 4.8, The value of Frequency decreased compared Fixed buildings with Lead rubber bearing and the Friction pendulum system by (50%, & 18%) respectively, While Hinge base increased by (10%) compared Fixed buildings, when the No. of storeys were 7. while when the No. of storeys 19 the value of Frequency decreased compared Fixed buildings with Lead rubber bearing and the Friction pendulum system by (34%, & 10%) respectively, While Hinge base increased by (8%) compared Fixed buildings.
d. As shown in Figure 4.9, the value of displacements increased compared Fixed buildings with (Lead rubber bearing, the Friction pendulum system, and Hinge base) by (179%, 166%, & 67%) respectively, when the No. of storeys were 7. while when the No. of storeys 19 the value of displacements increased compared Fixed buildings with (Lead rubber bearing, the Friction pendulum system, and Hinge base) by (93%, 88%, & 12%) respectively.

The value of the base shear, Time period and displacements increased as the No. of storeys increased, while the value of frequency decreased as the No. of storeys increased. The increase of base shear due to increase the height of building, also the increase lateral displacements of the buildings. The increases in time period due to decrease the stiffness of RC building and it have more displacements at tip of buildings, as shown below:

a. As shown in Figure 4.14, the value of base shear increased by (51%, 60% & 182%) when the No. of storeys increased from 7 to (10, 13 & 19) respectively, when use Fixed building, while its value increased by (30%, 95% & 249%) respectively, when use Lead rubber bearing, its value increased by (200%, 297% & 575%) respectively when use the Friction pendulum system, also its value increased by (24%, 50% & 170%) respectively, when use Hinge base.

b. As shown in Figure 4.7, the value of time period increased by (46%, 19% & 189%) when the No. of storeys increased from 7 to (10, 13 & 19) respectively, when use Fixed building, while its value increased by (23%, 46% & 88%) respectively, when use Lead rubber bearing, its value increased by (15%, 40% & 115%) respectively when use the Friction pendulum system, also its value increased by (38%, 75% & 140%) respectively, when use Hinge base.
c. As shown in Figure 4.8, the value of Frequency decreased by (31%, 48% & 65%) when the No. of storeys increased from 7 to (10, 13 & 19) respectively, when use Fixed building, while its value decreased by (20%, 32% & 48%) respectively, when use Lead rubber bearing, its value decreased by (10%, 30% & 55%) respectively when use the Friction pendulum system, also its value decreased by (28%, 43% & 60%) respectively, when use Hinge base.
d. As shown in Figure 4.17, the value of displacements increased by (73%, 130% & 488%) when the No. of storeys increased from 7 to (10, 13 & 19) respectively, when use Fixed building, while its value increased by (35%, 139% & 440%) respectively, when use Lead rubber bearing, its value increased by (11%, 104% & 375%) respectively when use the Friction pendulum system, also its value increased by (105%, 163% & 560%) respectively, when use Hinge base.

The value of the base shear, Time period, frequency and displacements increased when the No. of bay increased. The base shear, time period and roof displacements values increased when the No. of bay increased. However, it may lead to made to redistribution the internals forces and re-arranged the location of plastic hinges. as shown below:

a. As shown in Figure 4.6, 4.10, and 4.14, the value of base shear increased by (30%, & 45%) when the No. of bays increased from 3 to (4, & 5) respectively, when use Fixed building, while its value increased by (15%, & 25%) respectively, when use Lead rubber bearing, its value increased by (10%, & 15%) respectively when use the Friction pendulum system, also its value increased by (30%, & 61%) respectively, when use Hinge base.
b. As shown in Figure 4.7, 4.11, and 4.15, the value of time period increased by (2%, & 10%) when the No. of bays increased from 3 to (4, & 5) respectively, when use Fixed building, while its value increased by (5%, & 7%) respectively, when use Lead rubber

bearing, its value increased by (10%, & 15%) respectively when use the Friction pendulum system, also its value increased by (5%, & 10%) respectively, when use Hinge base.

c. As shown in Figure 4.8, 4.12, and 4.16, the value of Frequency increased by (3%, & 10%) when the No. of bays increased from 3 to (4, & 5) respectively, when use Fixed building, while its value increased by (5%, & 10%) respectively, when use Lead rubber bearing, its value increased by (8%, & 12%) respectively when use the Friction pendulum system, also its value increased by (3%, &15%) respectively, when use Hinge base.

d. As shown in Figure 4.9, 4.13, and 4.17, the value of displacements increased by (3%, & 25%) when the No. of bays increased from 3 to (4, & 5) respectively, when use Fixed building, while its value increased by (10%, & 15%) respectively, when use Lead rubber bearing, its value increased by (12%, & 15%) respectively when use the Friction pendulum system, also its value increased by (12%, & 15%) respectively, when use Hinge base.

***The Results When the Storey Height (3.1 m), Bay width (6 m) and No. of Bay=3:***

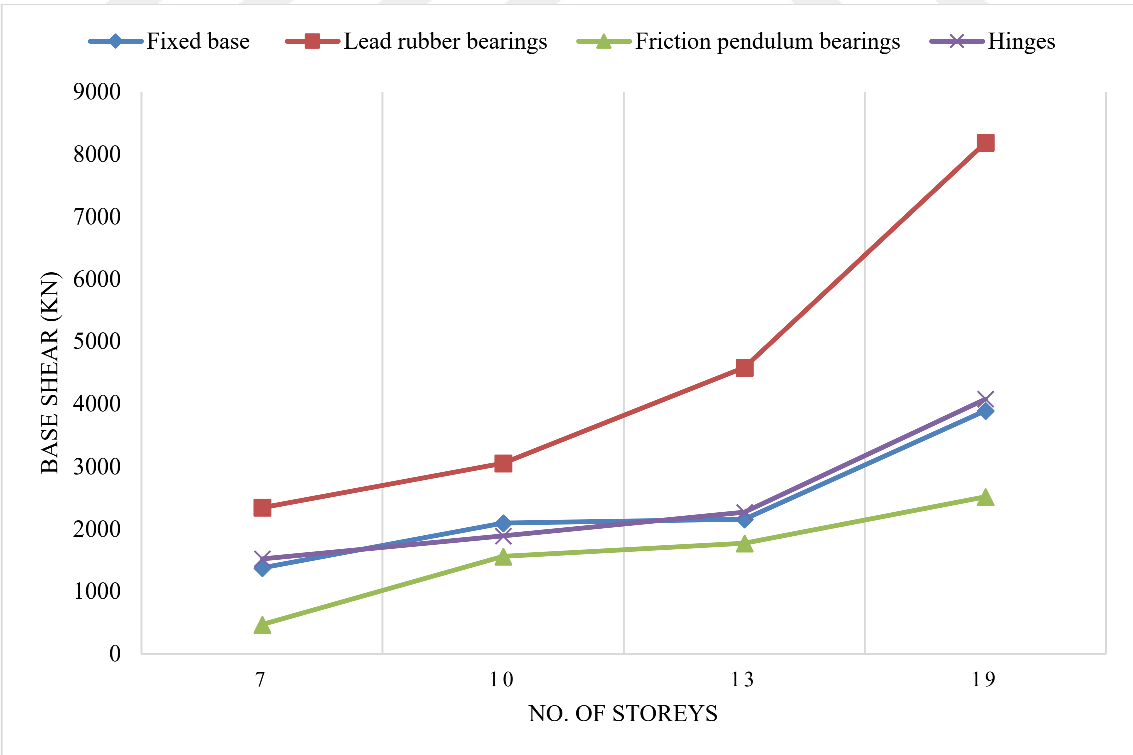



**Figure 4.6:** Maximum Base Shear Based on the No. of Storeys and Different Types of Isolators.

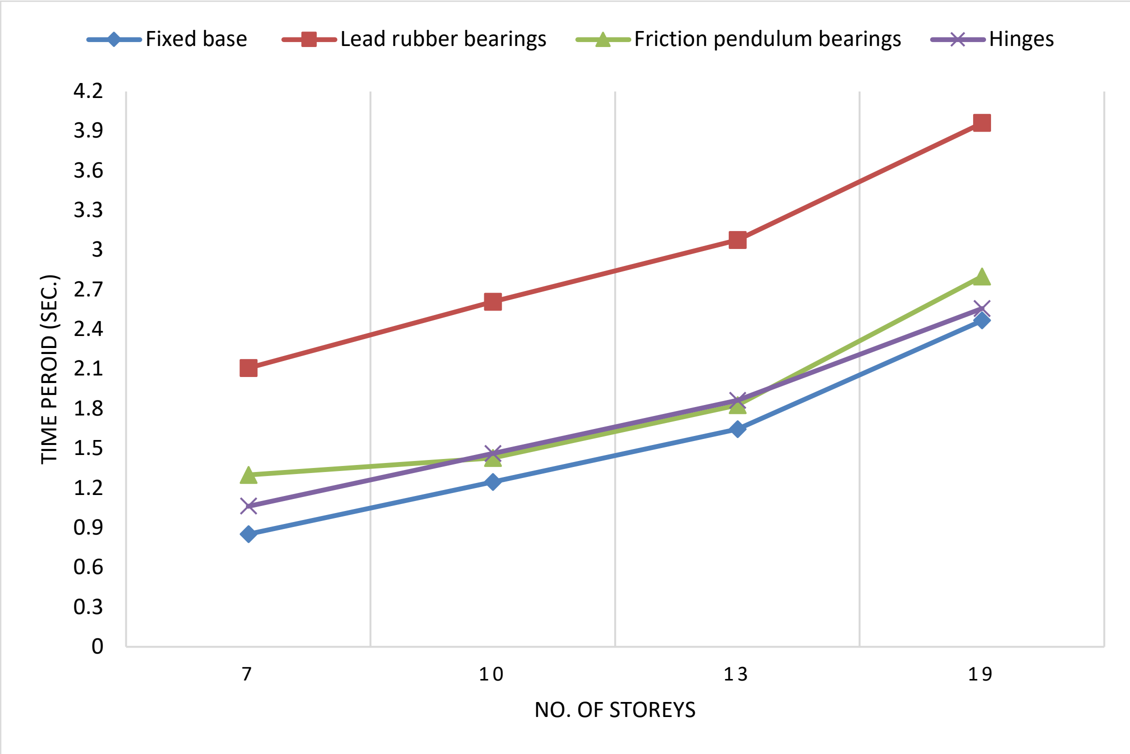



**Figure 4.7 :**Time Period Based on the No. of Storeys and Different Types of Isolators**.**

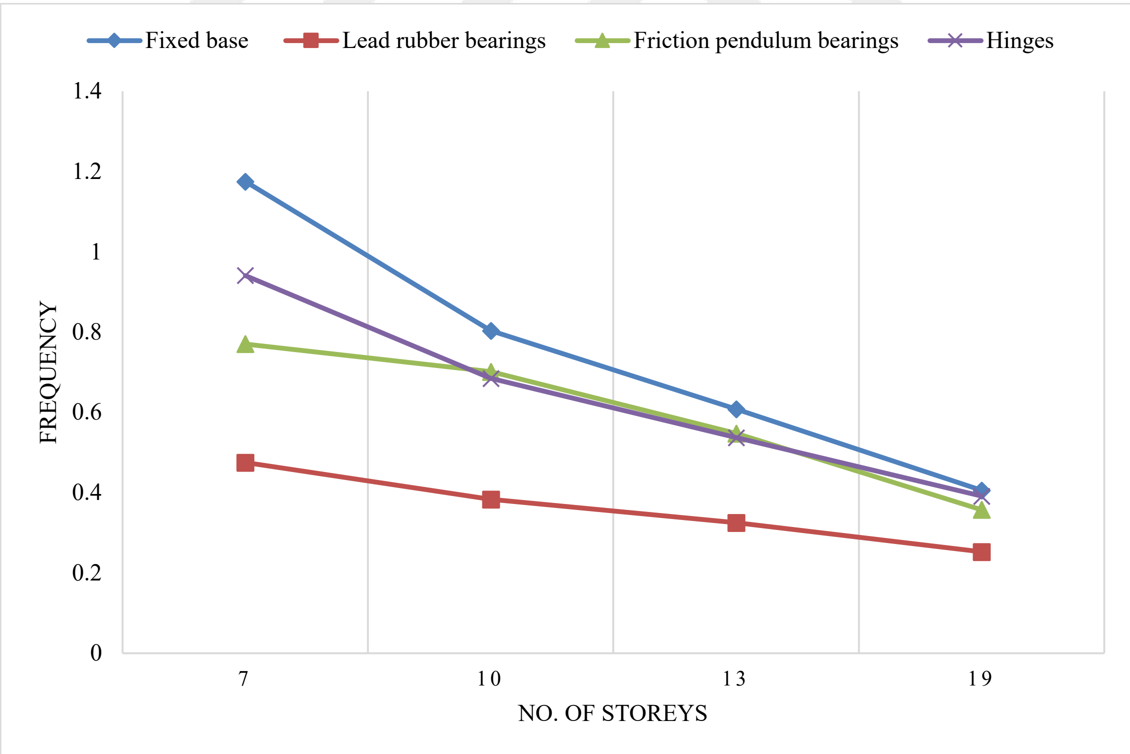



**Figure 4.8:** Frequency Based on the No. of Storeys and Different Types of Isolators.

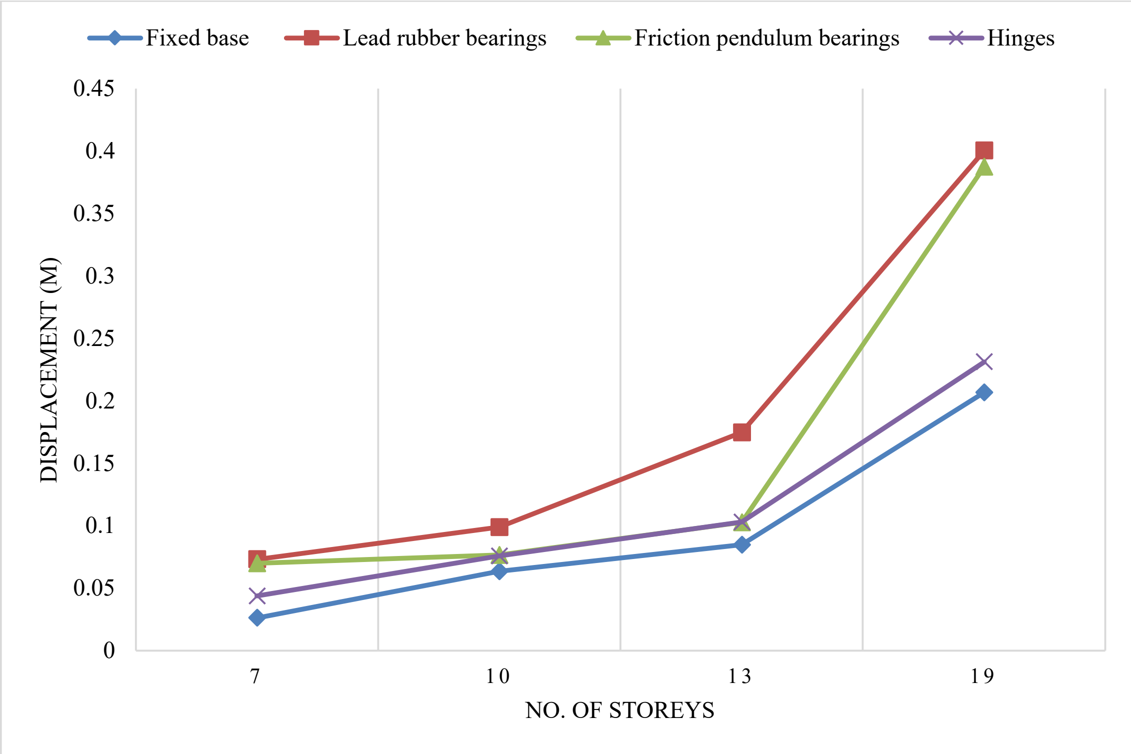



**Figure 4.9:** Roof Displacements in X Direction Based on the No. of Storeys and Dfferent Types of Isolators.

***The Results When the Storey Height (3.1 m), Bay width (6 m) and No. of Bay=4:***

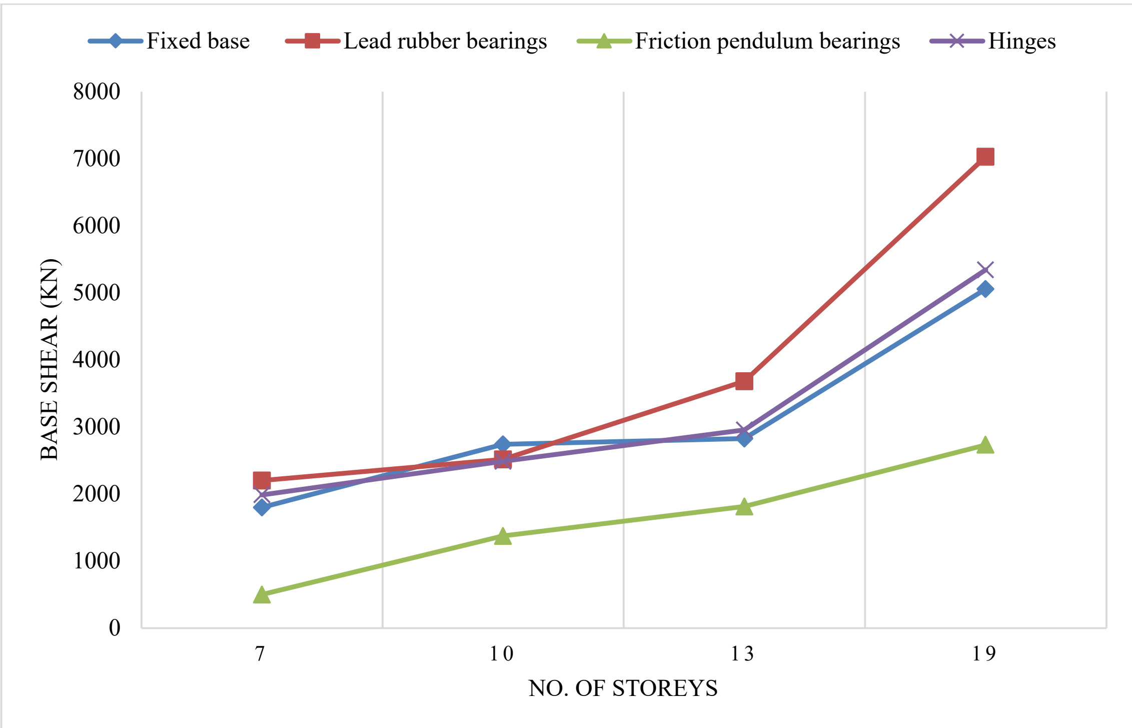



**Figure 4.10:** Maximum Base Shear Based on the No. of Storeys and Different Types of Isolators.

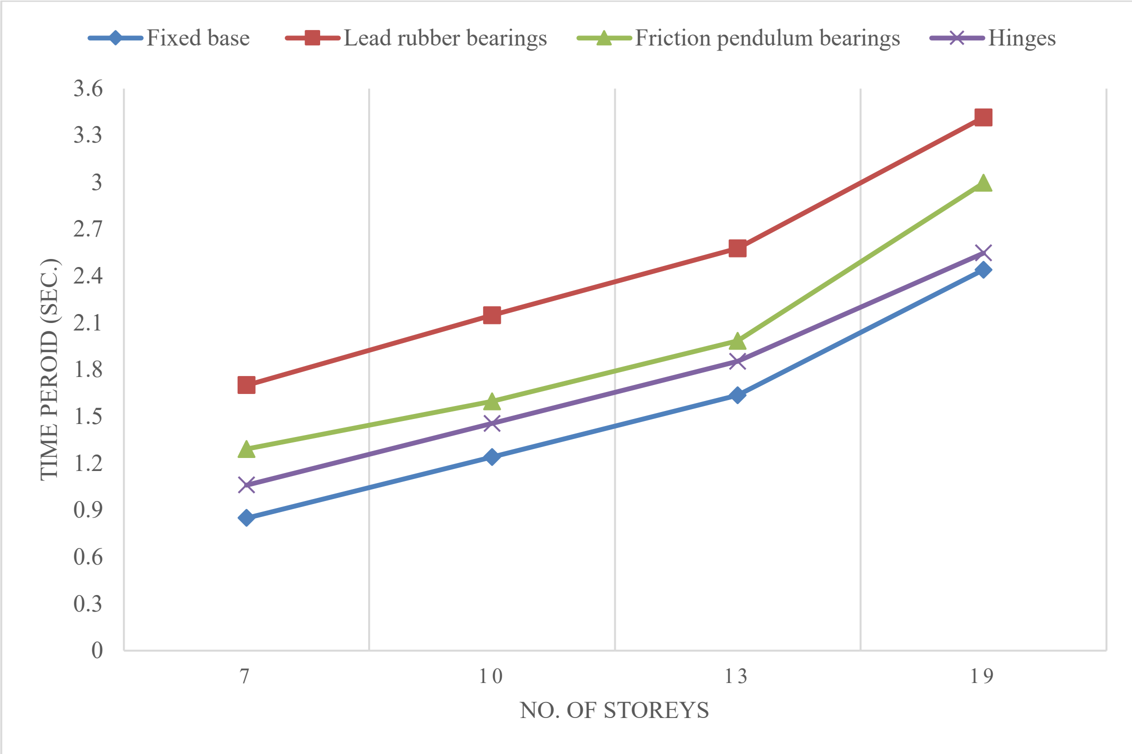



**Figure 4.11 :**Time Period Based on the No. of Storeys and Different Types of Isolators**.**

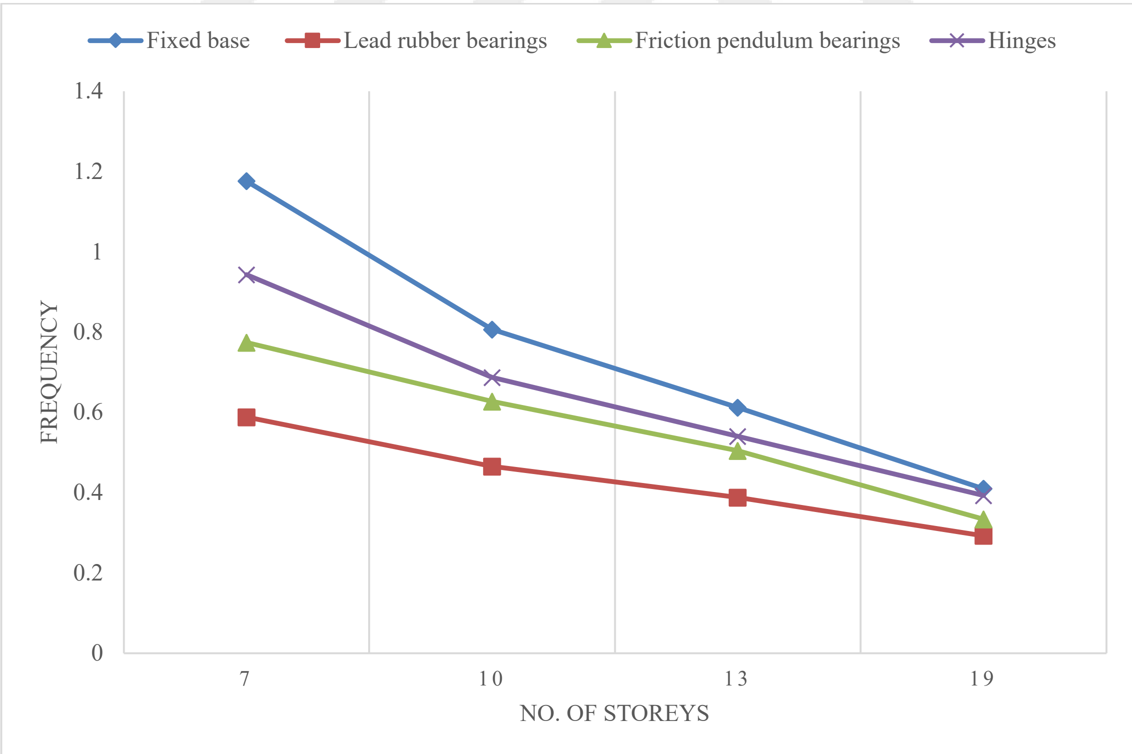



**Figure 4.12:** Frequency Based on the No. of Storeys and Different Types of Isolators.

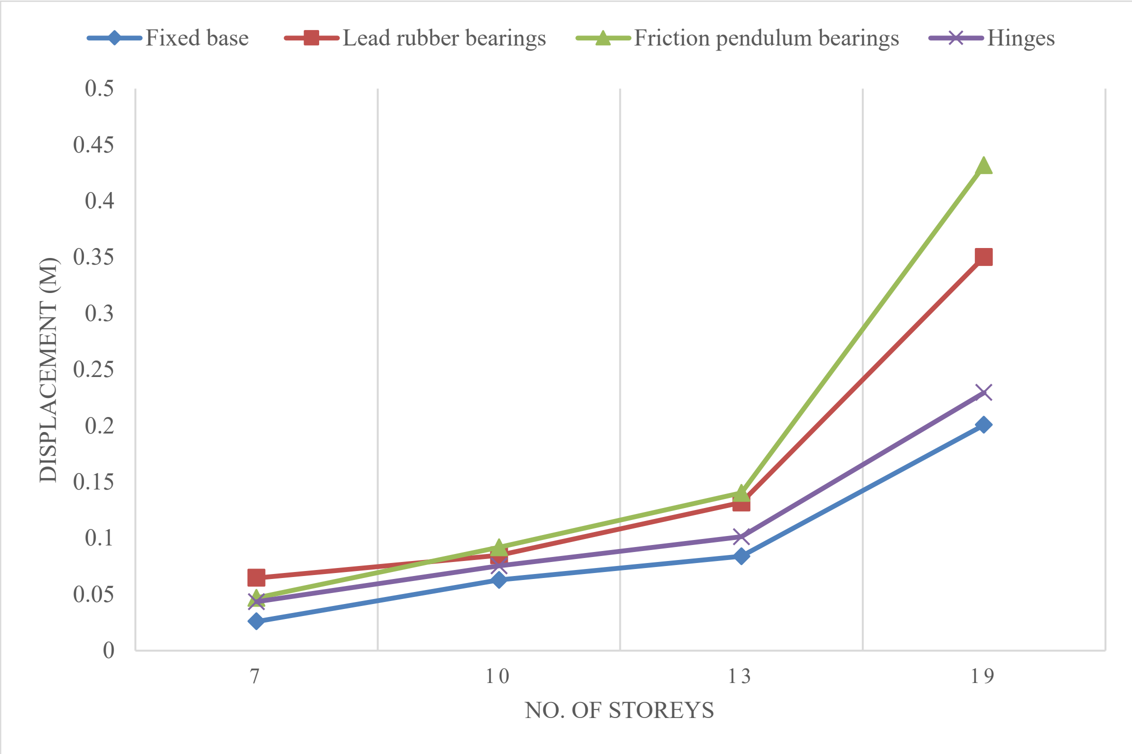



**Figure 4.13:** Roof Displacements in X Direction Based on the No. of Storeys and Different Types of Isolators

***The Results When the Storey Height (3.1 m), Bay width (6 m) and No. of Bay =5:***

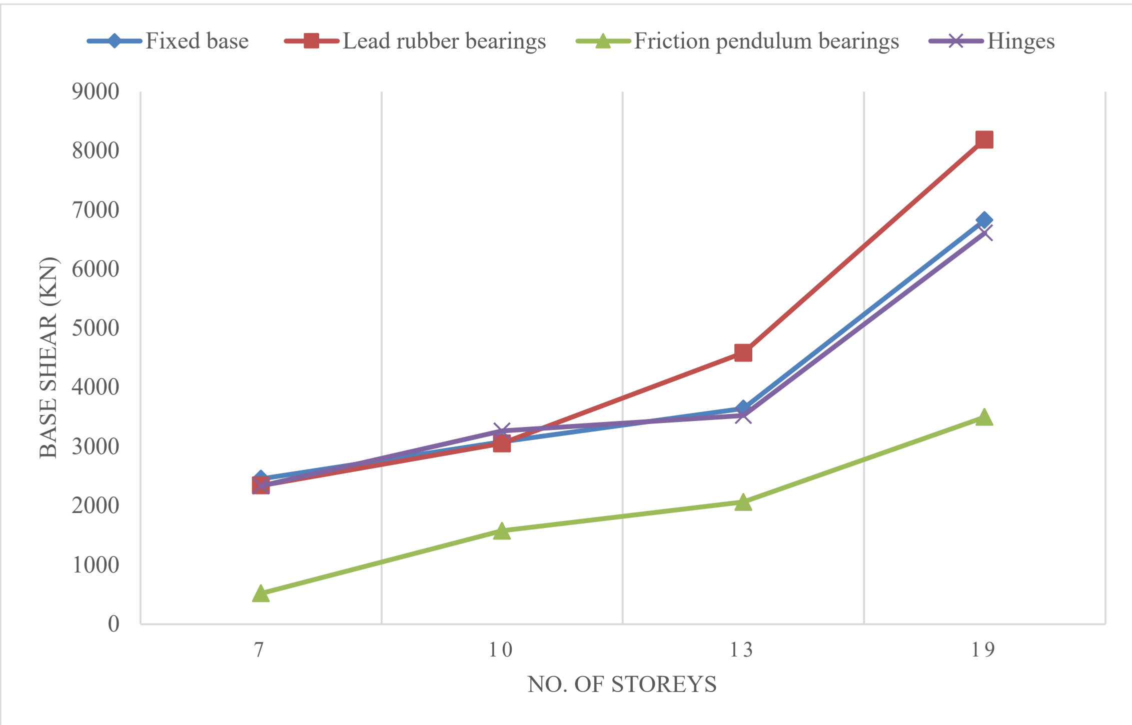



**Figure 4.14:** Maximum Base Shear Based on the No. of Storeys and Different Types of Isolators.

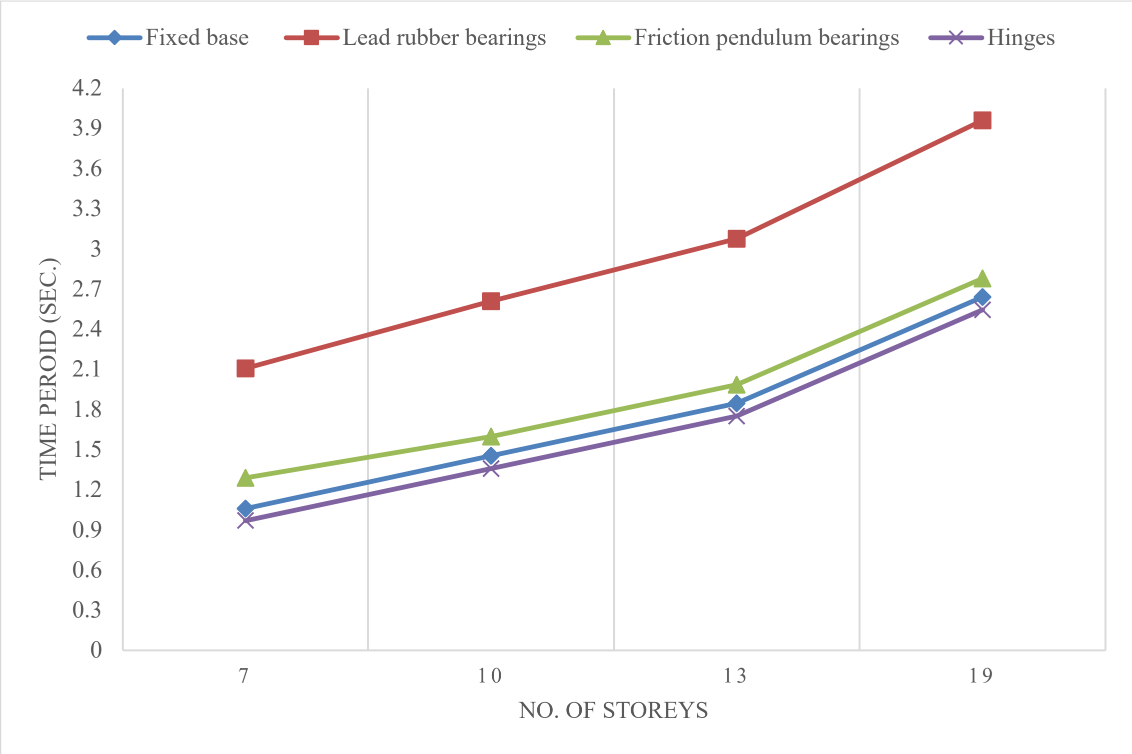



**Figure 4.15 :**Time Period Based on the No. of Storeys and Different types of Isolators.

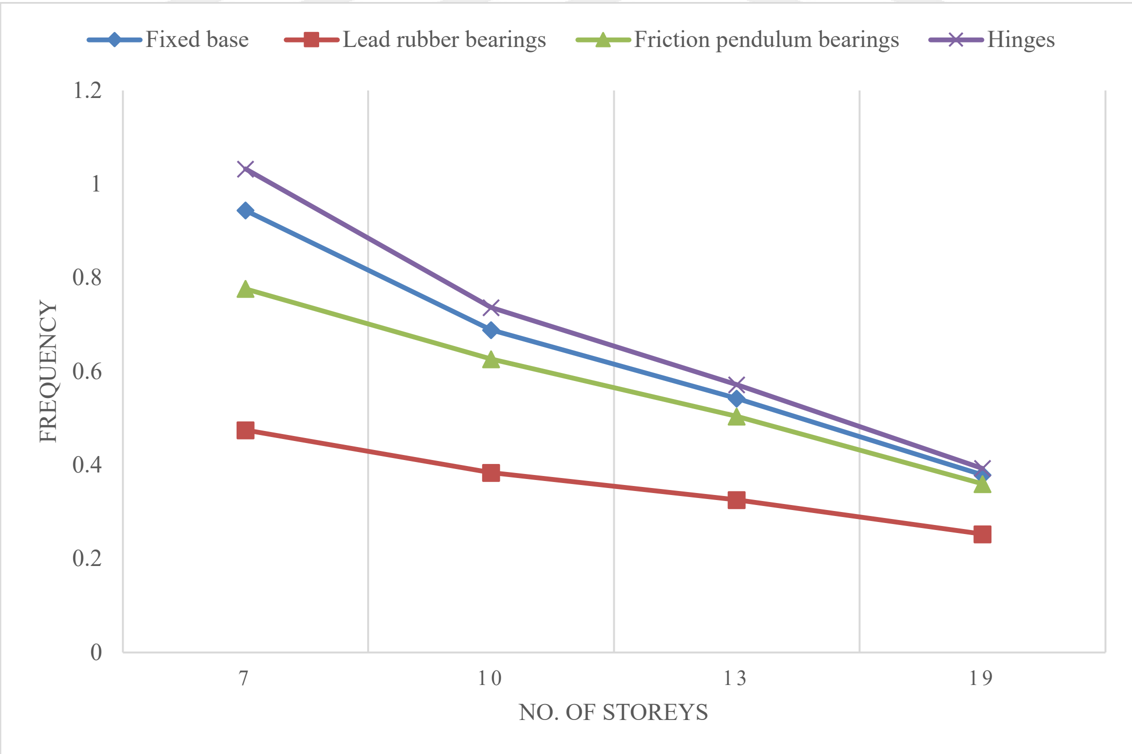



**Figure 4.16:** Frequency Based on the No. of Storeys and Different Types of Isolators.

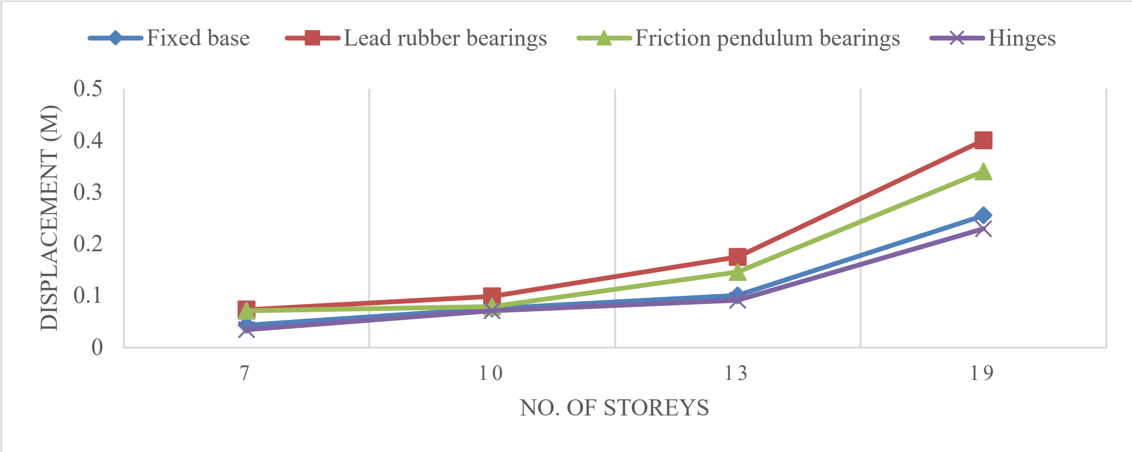



**Figure 4.17:** Roof Displacements in X Direction Based on the No. of Storeys and Different Types of Isolators.

#### 4.3.1.2 Storey drift of the buildings RC without shear wall

As shown in Figure 4.18, storey drift values were found for four buildings under the influence of changes in parameters various isolators (The Friction pendulum system, Lead rubber bearing, and Hinge base), number of storeys, and No. of bays. The storey drift results were presented in three cases for each building. The effect of the various isolators and number of storeys appeared in all cases, while the effect of the No. of bays appeared by comparing the first, second and third cases.

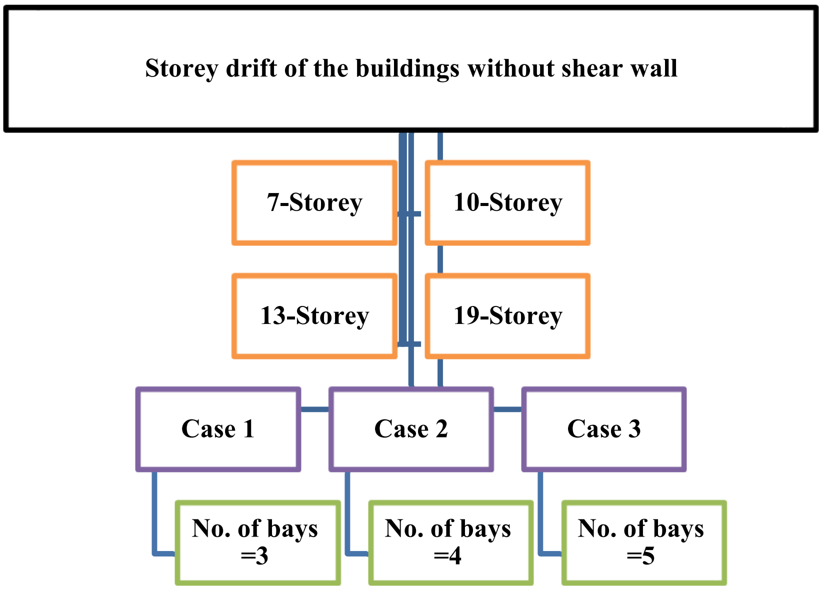



**Figure 4.18 :**Storey Drift of the Buildings without Shear Wall

a. As shown in Figure 4.19, The value of storey drift increased compared Fixed buildings with Lead rubber bearing and the Friction pendulum system by (60%, & 45%)

respectively, While Hinge base decreased by (27%) compared Fixed buildings, when the No. of storeys were 7. while when the No. of storeys 19 the value of story drift increased compared Fixed buildings with Lead rubber bearing by (38%), While the Friction pendulum system and Hinge base decreased by (88%, & 10%) respectively, compared Fixed buildings.

b. As shown in Figure 4.22, 4.23, and 4.24, the value of story drift decreased by (16%, & 20%) when the No. of bays increased from 3 to (4, & 5) respectively, when use Fixed building, while its value increased by (10%, & 20%) respectively, when use Lead rubber bearing, its value increased by (40%, & 60%) respectively when use the Friction pendulum system, also its value increased by (5%, & 10%) respectively, when use Hinge base.

c. As shown in Figure 4.21, 4.24, 4.27, and 4.30, the value of story drift increased by (60%, 110% & 515%) when the No. of storeys increased from 7 to (10, 13 & 19) respectively, when use Fixed building, while its value increased by (30%, 210% & 390%) respectively, when use Lead rubber bearing, its value increased by (80%, 120% & 150%) respectively when use the Friction pendulum system, also its value increased by (100%, 160% & 545%) respectively, when use Hinge base.

***The Results of Storey Drift When the No. of storeys were 7:***

Case 1:

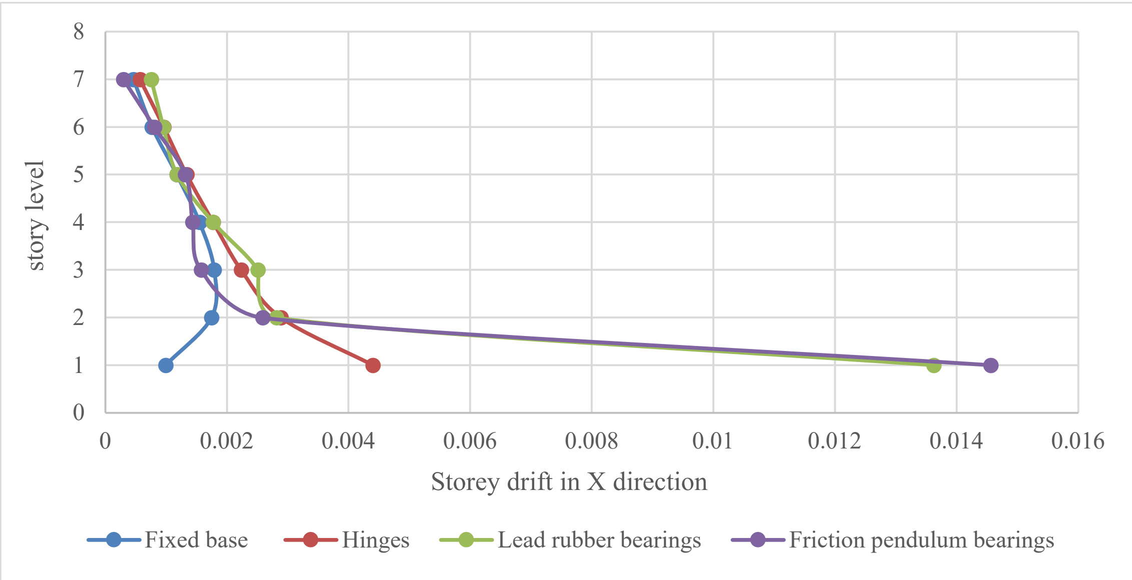



**Figure 4.19:** Storey Drift in X Direction When the No. of Storeys were 7.

Case 2:

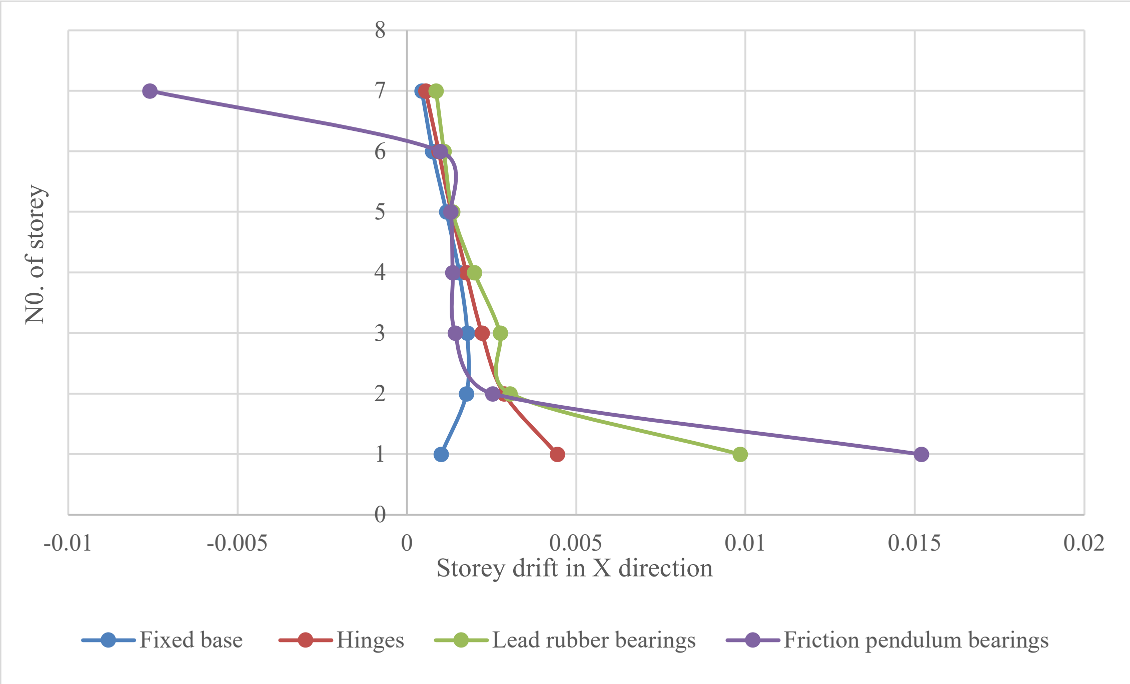



**Figure 4.20:** Storey Drift in X Direction When the No. of Storeys were 7

Case 3:

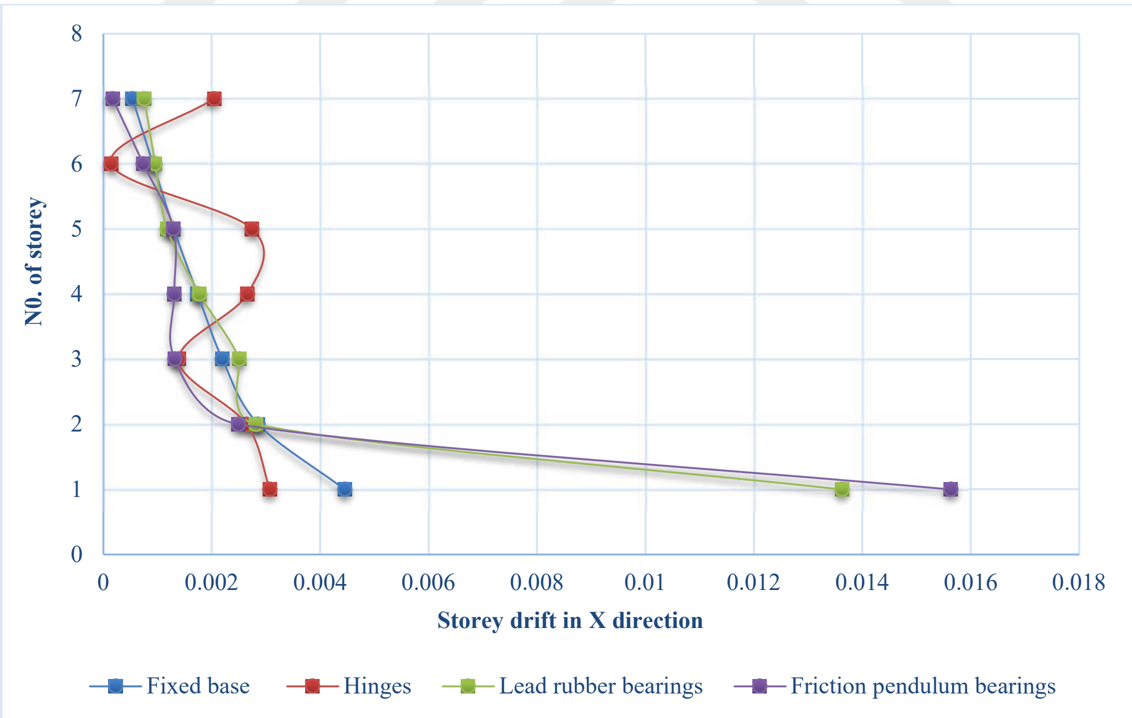



**Figure 4.21:** Storey Drift in X Direction When the No. of Storeys were 7.

***The Results of Storey Drift When the No. of storeys were 10:***

Case 1:

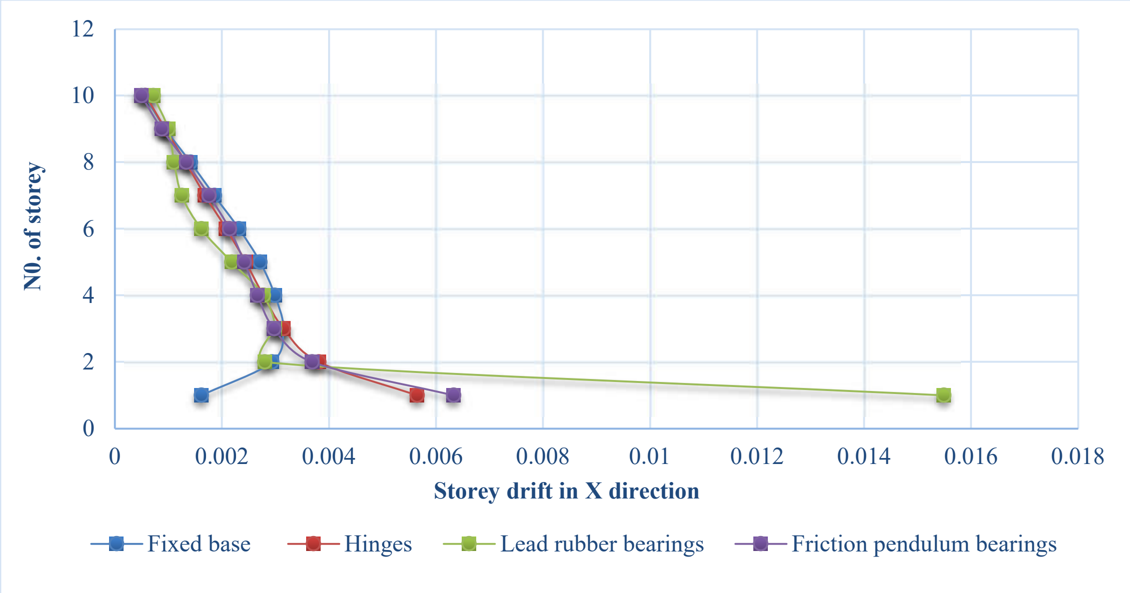



**Figure 4.22:** Storey Drift in X Direction When the No. of Storeys were 10.

Case 2:

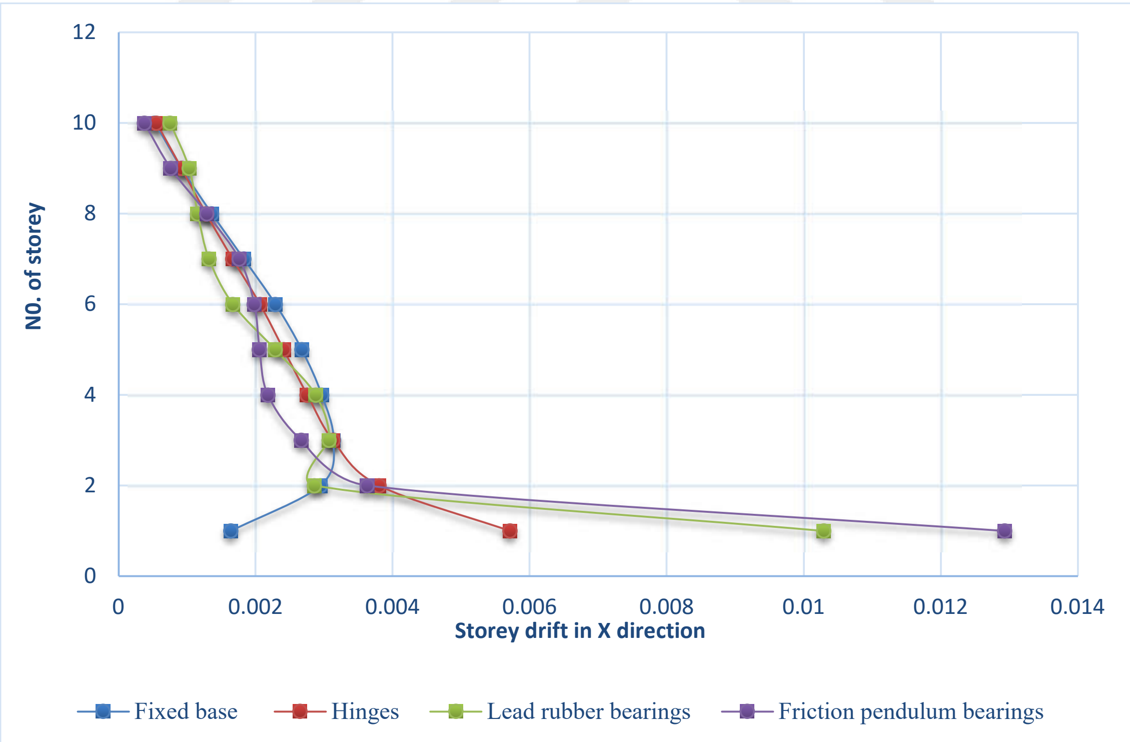



**Figure 4.23:** Storey Drift in X Direction When the No. of Storeys were 10.

*Case 3:*

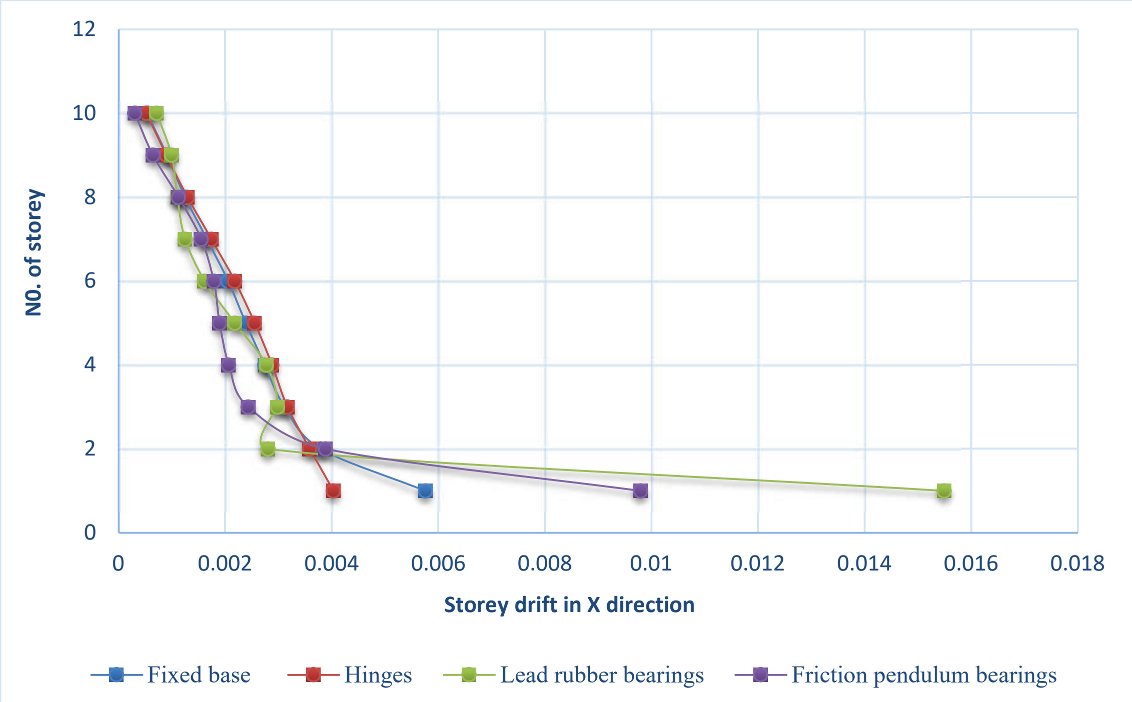



**Figure 4.24:** Storey Drift in X Direction When the No. of Storeys were 10

***The Results of Storey Drift When the No. of storeys were 13:***

Case 1:

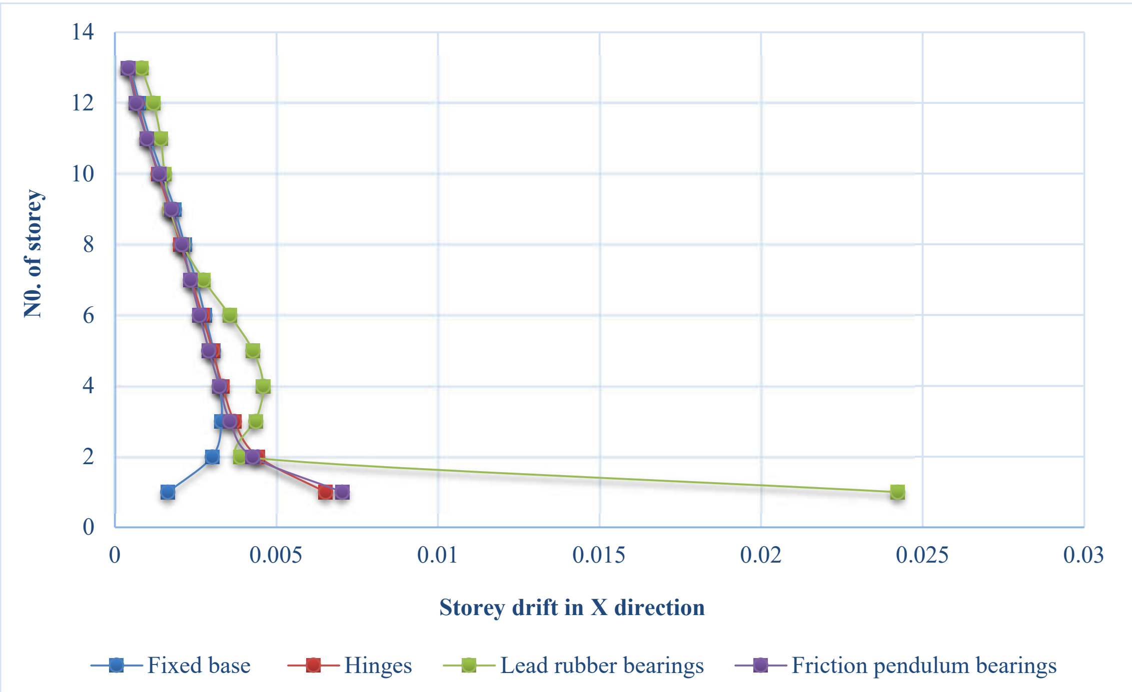



**Figure 4.25:** Storey Drift in X Direction When the No. of Storeys were 13.

Case 2:

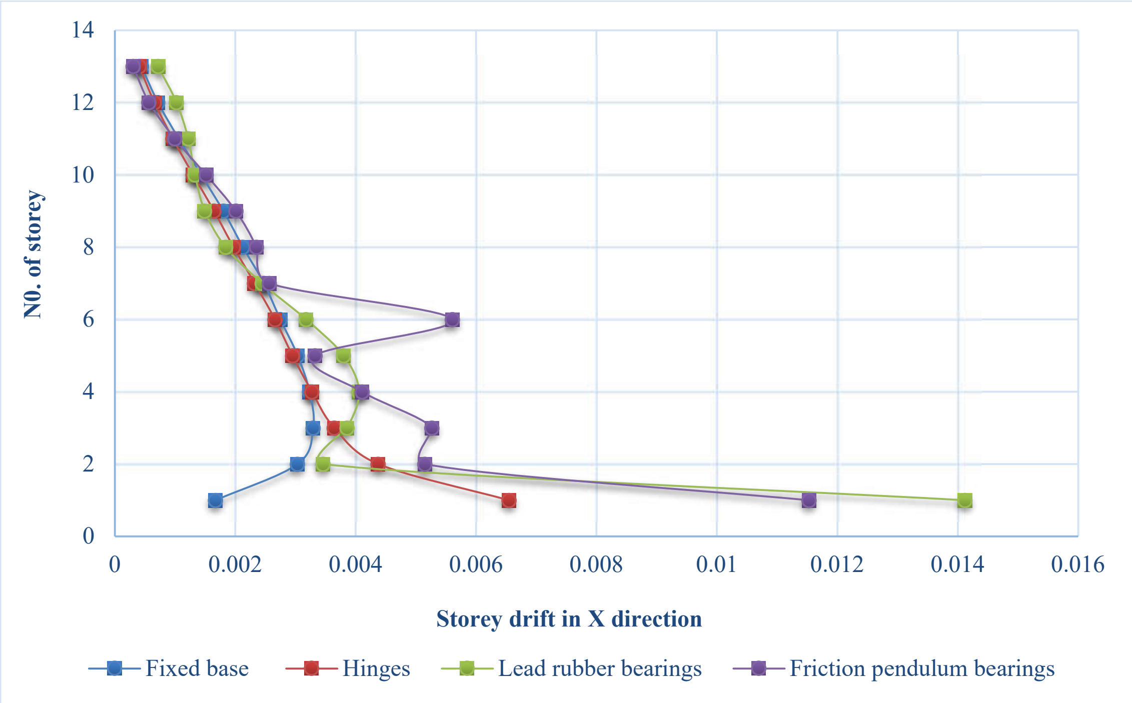



**Figure 4.26:** Storey Drift in X Direction When the No. of Storeys were 13.

Case 3:

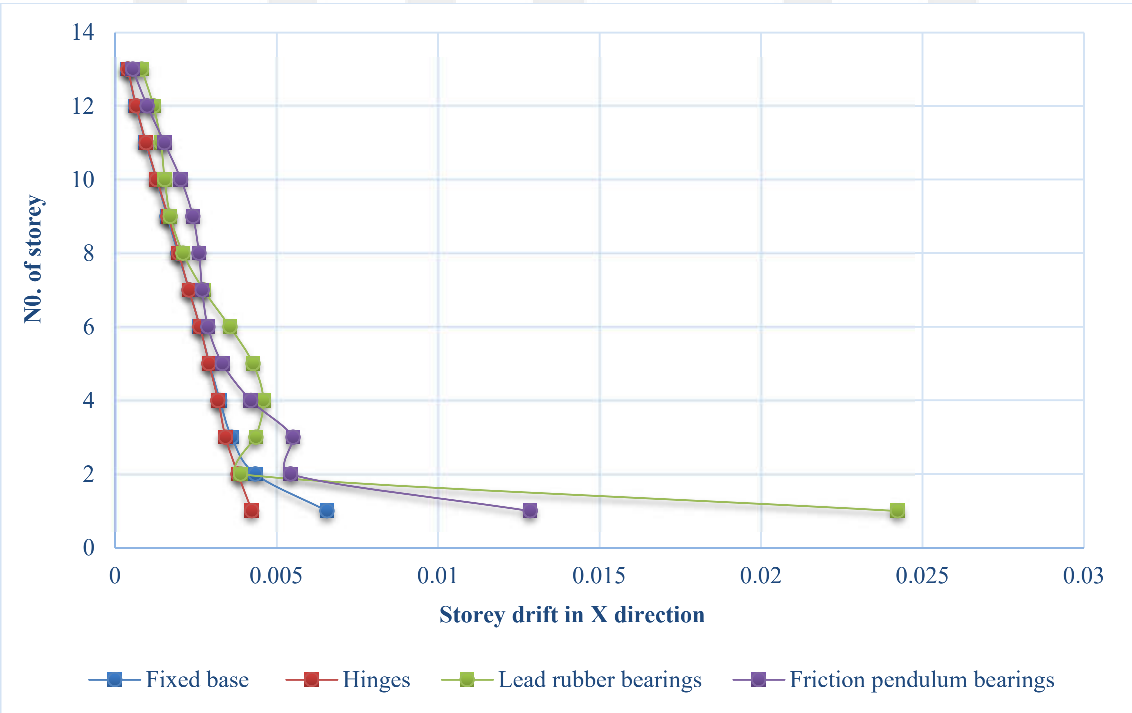



**Figure 4.27:** Storey Drift in X Direction When the No. of Storeys were 13.

*The Results of Storey Drift When the No. of storeys were 19:*

Case 1:

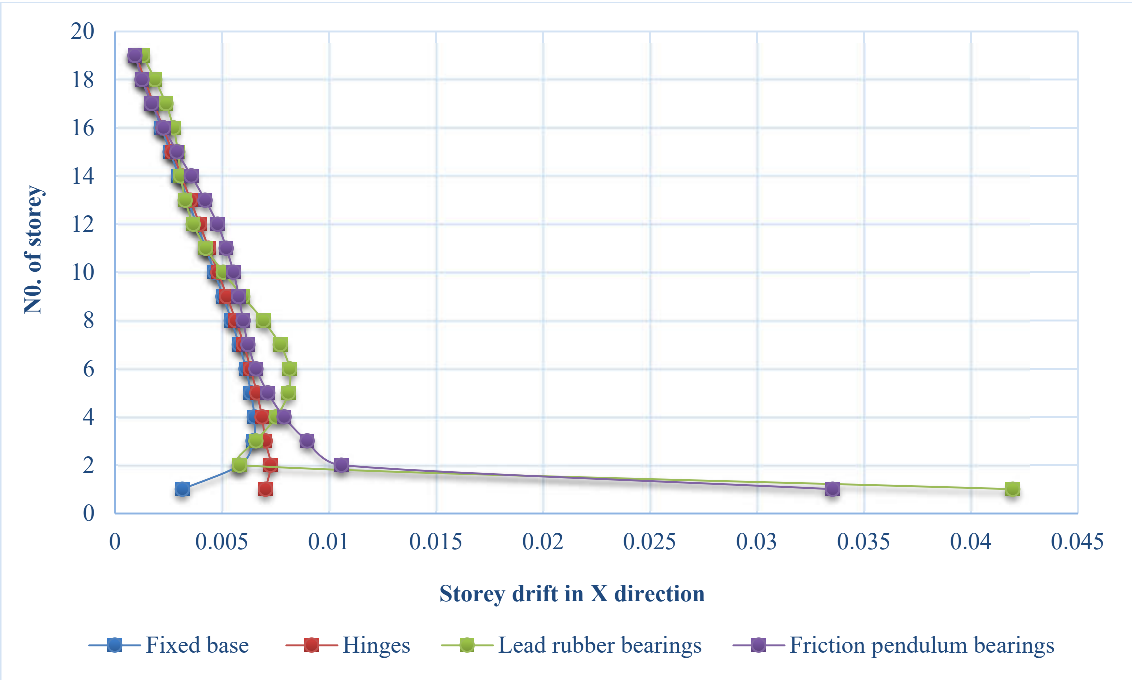



**Figure 4.28:** Storey Drift in X Direction When the No. of Storeys were 19.

Case 2:

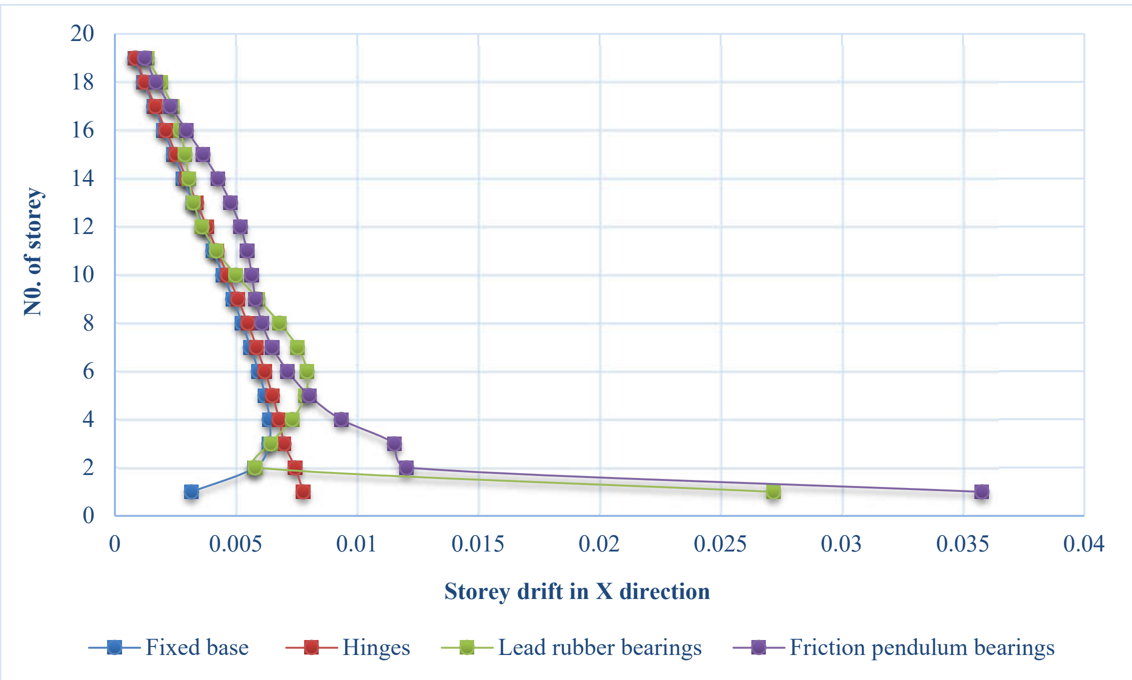



**Figure 4.29**: Storey Drift in X Direction When the No. of Storeys were 19.

Case 3:

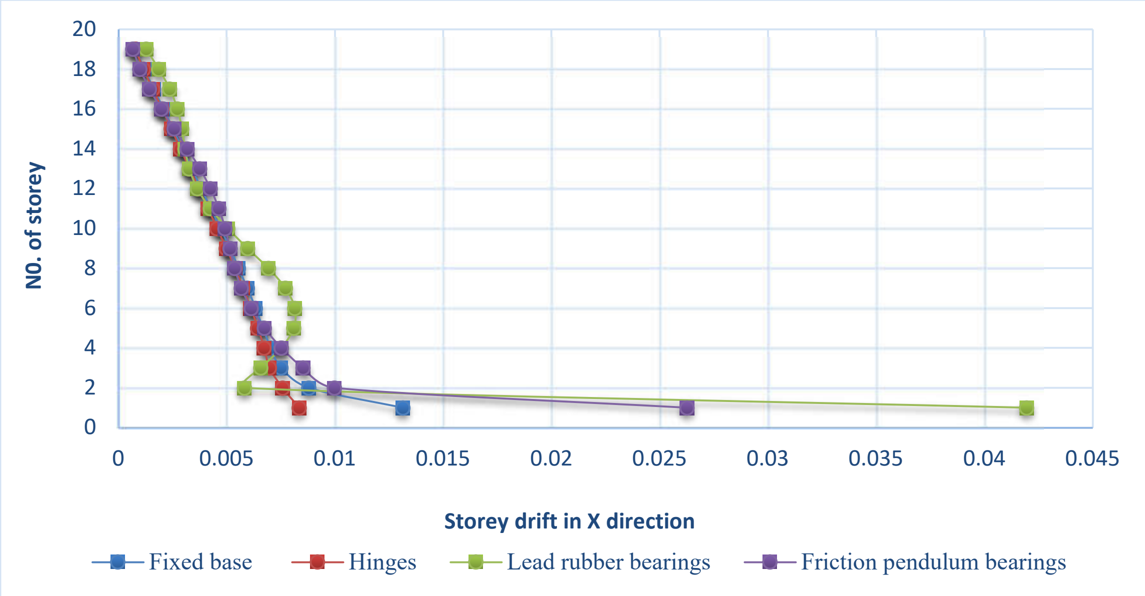



**Figure 4.30:** Storey Drift in X Direction When the No. of Storeys were 19.

### 4.3.2 Modeling Results of Buildings RC with Shear Wall

Buildings with shear walls were analyzed and the results obtained were compared with the results of buildings without shear walls. The results were compared for the same building characteristics in terms of various isolators (The Friction pendulum system, Lead rubber bearing, and Hinge base), number of storeys, and No. of bays.

#### 4.3.2.1 The effect of various isolators (The Friction pendulum system, Lead rubber bearing, and Hinge base) with the presence of shear walls:

a. In the case absence of shear walls as shown in Figure 4.6, when the No. of storeys were 7 the base shear values were (1375, 471, 2342 and 1522) kN, when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively, and when the No. of storeys were 19 the base shear values were (3892, 2516, 8186 and 4081) kN, when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively. While in the case presence of shear walls as shown in Figure 4.37, when the No. of storeys were 7 the base shear values were (1600, 977, 2440 and 1605) kN, when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively, and when the No. of storeys were 19 the base shear values were (5647, 4257, 6426 and 5657) kN, when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively.

b. In the case absence of shear walls as shown in Figure 4.7, when the No. of storeys were 7 the time period values were (0.851, 1.298, 2.106 and 1.062) sec, when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively, and when the No. of storeys were 19 the time period values were (2.466, 2.799, 3.959 and 2.557) sec, when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively. While in the case presence of shear walls as shown in Figure 4.38, when the No. of storeys were 7 the time period values were (0.270, 1.066, 2.263 and 0.289) sec, when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively, and when the No. of storeys were 19 the time period values were (1.253, 1.989, 3.933, and 1.253) sec, when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively.

c. In the case absence of shear walls as shown in Figure 4.8, when the No. of storeys were 7 the Frequency values were (1.174, 0.770, 0.474 and 0.941), when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively, and when the No. of storeys were 19 the Frequency values were (0.405, 0.357, 0.252, and 0.391), when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively. While in the case presence of shear walls as shown in Figure 4.39, when the No. of storeys were 7 the Frequency values were (3.69, 0.937, 0.441 and 3.68), when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively, and when the No. of storeys were 19 the Frequency values were (0.798, 0.502, 0.254, and 0.797), when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively.

d. In the case absence of shear walls as shown in Figure 4.9, when the No. of storeys were 7 the displacement values were (0.0262, 0.0699, 0.0731, and 0.0438) m , when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively, and when the No. of storeys were 19 the displacement values were (0.2067, 0.3874, 0.4003, and 0.2312) m, when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively. While in the case presence of shear walls as shown in Figure 4.40, when the No. of storeys were 7 the displacement values were (0.0015, 0.072, 0.0601, and 0.0018) m, when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively, and when the No. of storeys were 19 the displacement values were (0.00289, 0.0333, 0.2182, and 0.290) m, when various isolators were (Fix base, The Friction pendulum system, Lead rubber bearing, and Hinge base) respectively.

#### 4.3.2.2 The effect of the No. of storeys with the presence of shear walls:

a. As shown in Figure 4.10, the value of base shear (1800, 2740, 2823, 5055) kN, when the No. of storeys increased from 7 to (10, 13, and 19) respectively, when use Fixed building, while its value (2200, 2513, 3678, and 7028) kN, respectively, when use Lead rubber bearing, its value (499, 1373, 1810, and 2734) kN, respectively when use the Friction pendulum system, also its value (1989, 2483, 2953, and 5343) kN, respectively, when use Hinge base. While in the case presence of shear walls as shown in Figure 4.41, the value of base shear (1902, 3352, 4275, and 6113) kN, when the No. of storeys increased from 7 to (10, 13, and 19 ) respectively, when use Fixed building, While its value ( 2871, 4442, 4834, and 7817) respectively, when use Lead rubber bearing, its value (908, 1369, 1975, and 2706) kN, respectively when use the Friction pendulum system, also its value ( 1910, 3364, 4285, and 6988) kN, respectively, when use Hinge base.
b. As shown in Figure 4.11, the value of time period (0.8502, 1.2406, 1.6350, and 2.4395) sec, when the No. of storeys increased from 7 to (10, 13, and 19 ) respectively, when use Fixed building, While its value ( 1.7008, 2.1481, 2.5765, and 3.4155) sec, respectively, when use Lead rubber bearing, its value ( 1.2920, 1.5958, 1.9837, and 2.9959) sec, respectively when use the Friction pendulum system, also its value (1.0607, 1.4559, 1.8518, and 2.5470) sec, respectively, when use Hinge base. While in the case presence of shear walls as shown in Figure 4.42, the value of time period (0.2956, 0.5113, 0.7613, and 1.9578 ) sec, when the No. of storeys increased from 7 to (10, 13, and 19) respectively, when use Fixed building, While its value (1.7280, 2.0854, 2.4303, and 3.9111) sec, respectively, when use Lead rubber bearing, its value (1.0589, 1.3177 , 1.5779, and 2.1399) sec, respectively when use the

Friction pendulum system, also its value (0.2966, 0.5122, 0.7622, and 1.3336) sec, respectively, when use Hinge base.

c. As shown in Figure 4.12, the value of Frequency (1.1761, 0.8060, 0.6116, and 0.4099) when the No. of storeys increased from 7 to (10, 13, and 19) respectively, when use Fixed building, while its value (0.5879, 0.4655, 0.3881, and 0.2927) respectively, when use Lead rubber bearing, its value (0.7739, 0.6266, 0.5041, and 0.3337) respectively, when use the Friction pendulum system, also its value (0.9427, 0.6868 ,0.5399, and 0.3926) respectively, when use Hinge base. While in the case presence of shear walls as shown in Figure 4.43, the value of Frequency (3.382, 1.9557, 1.3135, 0.5107) when the No. of storeys increased from 7 to (10, 13, and 19 ) respectively, when use Fixed building, While its value (0.5786, 0.4795, 0.4114, and 0.2556) respectively, when use Lead rubber bearing, its value (0.9443, 0.7588, 0.6337, and 0.4673) respectively, when use the Friction pendulum system, also its value (3.3707, 1.952, 1.3118, and 0.7498) respectively, when use Hinge base.
d. As shown in Figure 4.13, the value of displacements (0.0261, 0.0629, 0.0838, and 0.2009) m, when the No. of storeys increased from 7 to (10, 13, and 19) respectively, when use Fixed building, while its value (0.0648, 0.0846, 0.1318, and 0.3502) m respectively, when use Lead rubber bearing, its value (0.0469, 0.0918, 0.1403, and 0.4317) m respectively, when use the Friction pendulum system, also its value (0.0435, 0.0752, 0.1013, and 0.2295) m respectively, when use Hinge base. While in the case presence of shear walls as shown in Figure 4.44, the value of displacements (0.0018, 0.0062, 0.0152, and 0.0406) m, when the No. of storeys increased from 7 to (10, 13, and 19 ) respectively, when use Fixed building, While its value (0.0349, 0.0602, 0.0765, and 0.2302) m respectively, when use Lead rubber bearing, its value ( 0.0682, 0.1085, 0.1666, and 0.2812 ) m respectively when use the Friction pendulum system, also its value (0.0018, 0.0062, 0.0152, and 0.0362) m respectively, when use Hinge base.

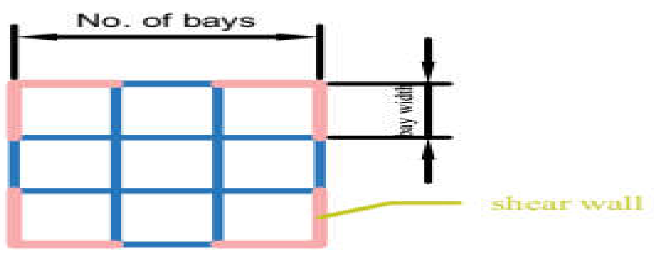



**Figure 4.31:** Plan of the Building (Shows the Location of the Shear Walls) Case 1.

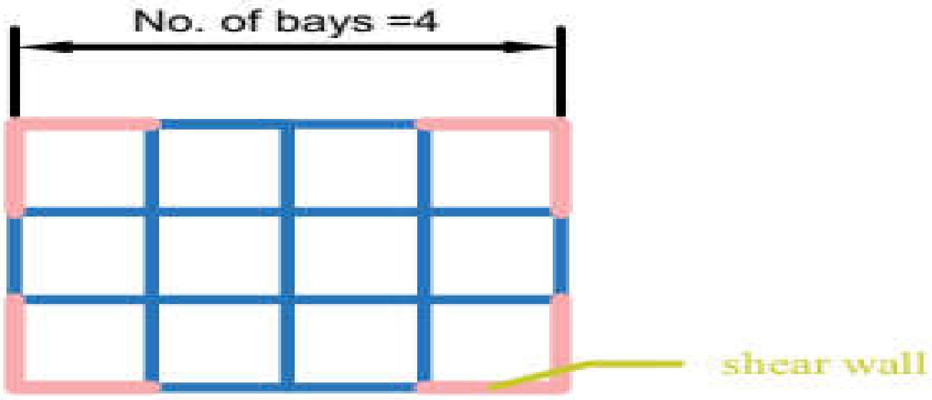



**Figure 4.32:** Plan of the Building (Shows the Location of the Shear Walls) Case 2.

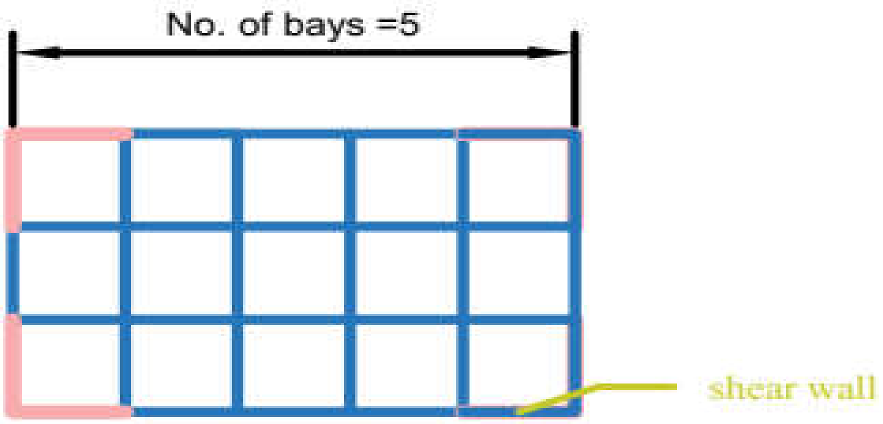



**Figure 4.33:** Plan of the Building (Shows the Location of the Shear Walls) Case 3.

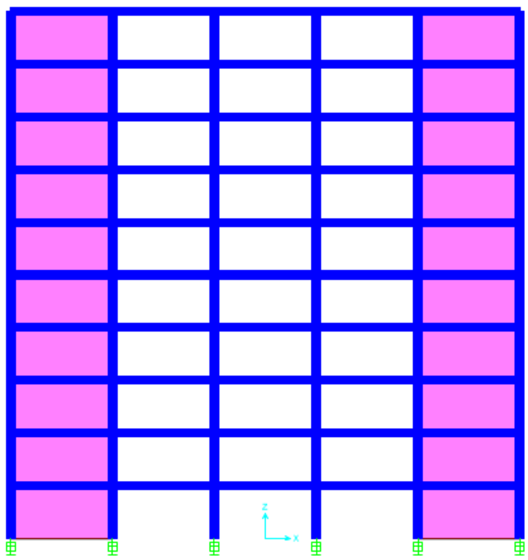


**Figure 4.34:** 2D Model of 10 Storey with Lead Rubber Bearing with Shear Wall.

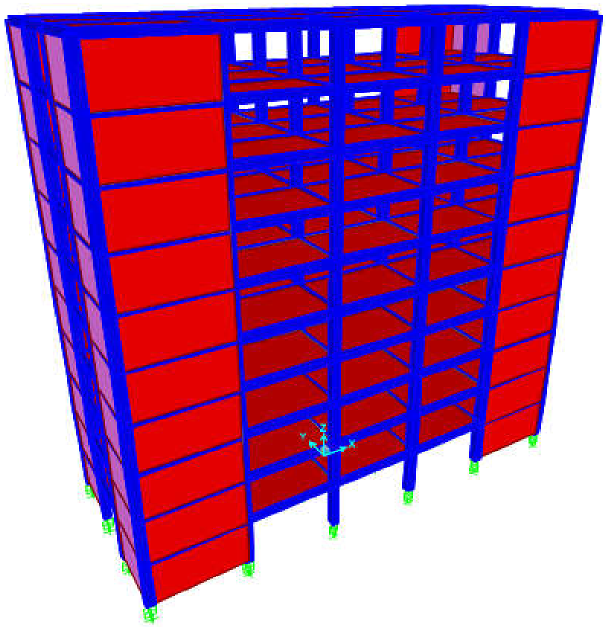


**Figure 4.35:** 3D Model of 10 Storey with Lead Rubber Bearing with Shear Wall

***The Results When the Storey Height (3.1 m), Bay width (6 m) and No. of Bay =3:***

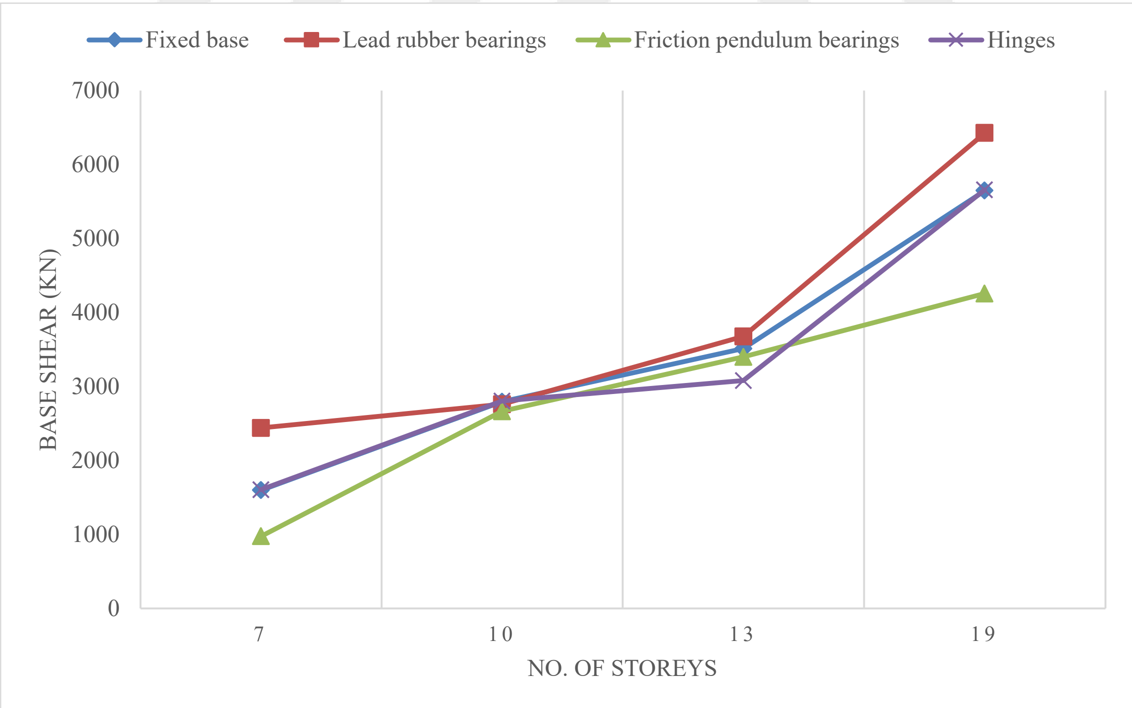



**Figure 4.36:** Maximum Base Shear Based on the No. of Storeys and Different Types of Isolators

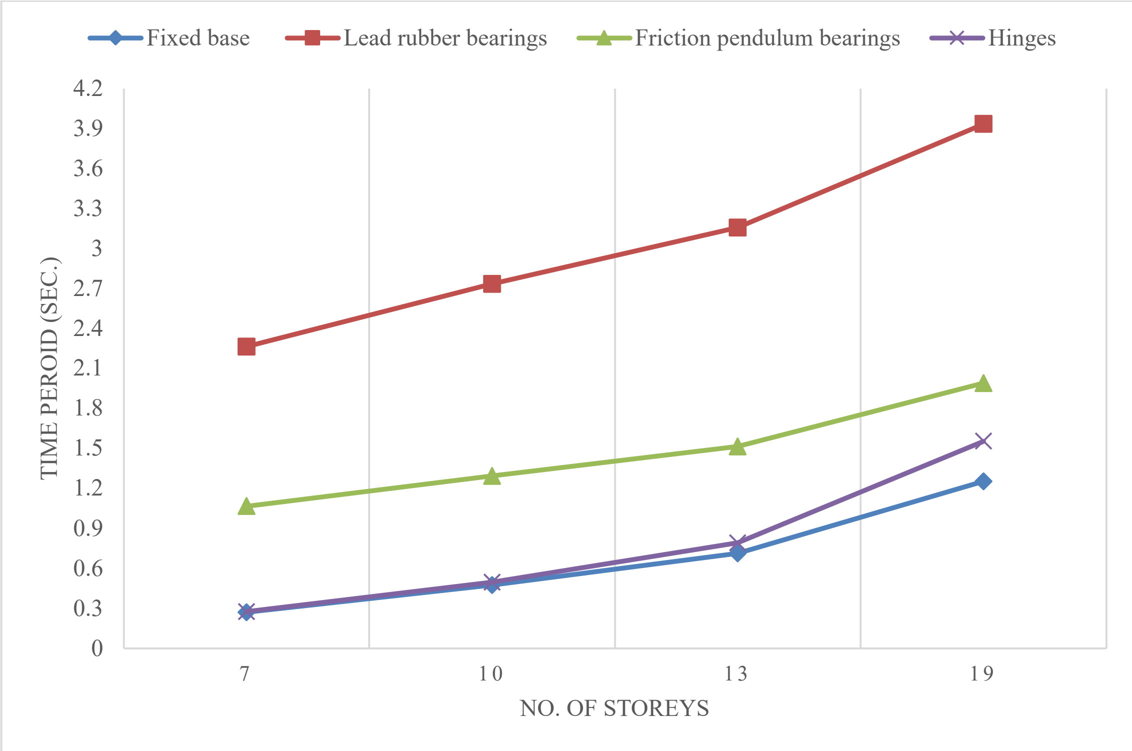



**Figure 4.37:** Time Period Based on the No. of Storeys and Different Types of Isolators

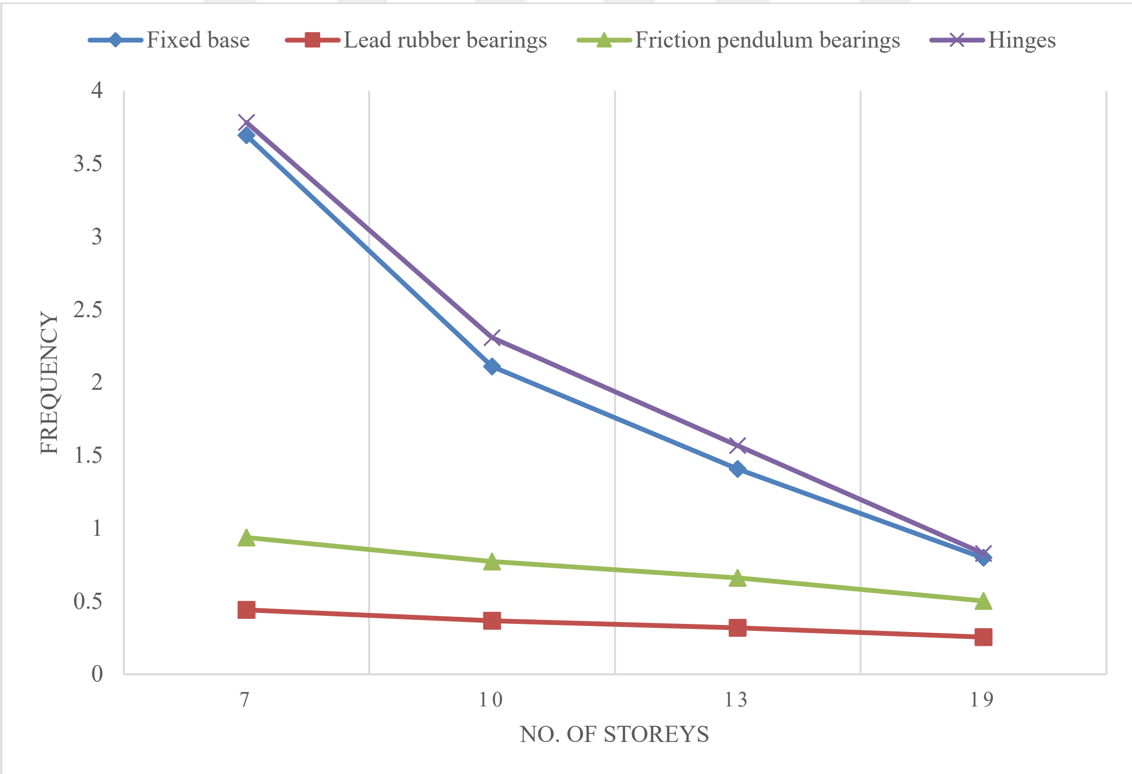



**Figure 4.38:** Frequency Based on the No. of Storeys and Different Types of Isolators

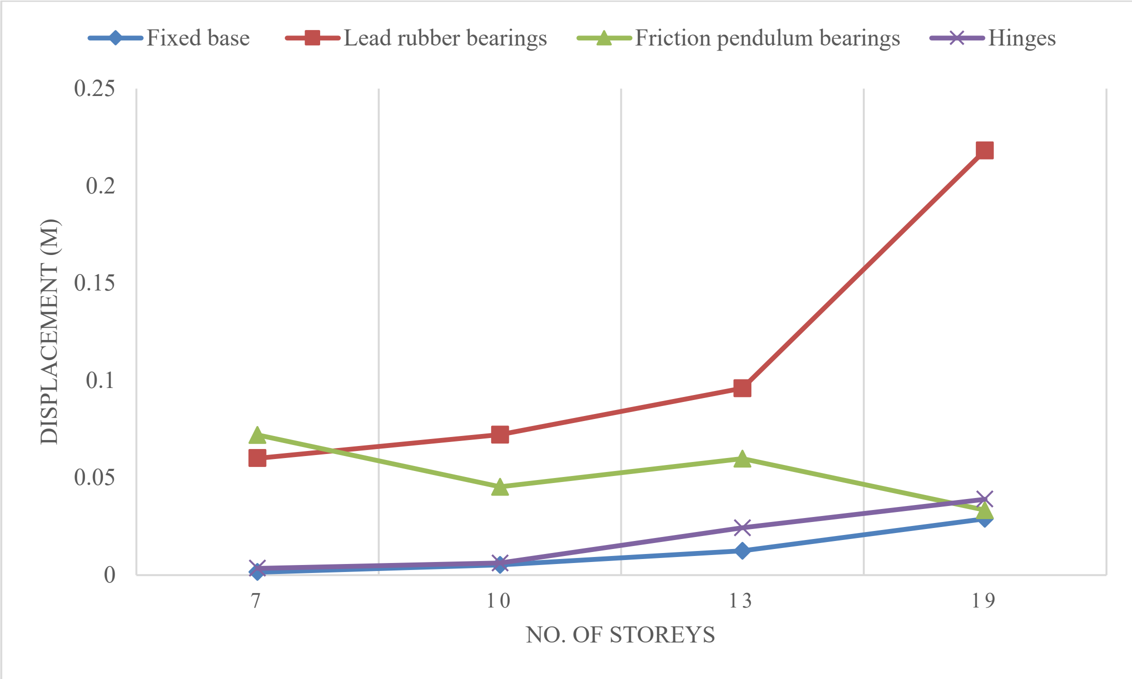



**Figure 4.39:** Roof Displacements in X Direction Based on the No. of Storeys and Different Types of Isolators

***The Results When the Storey Height (3.1 m), Bay width (6 m) and no. of Bay=4:***

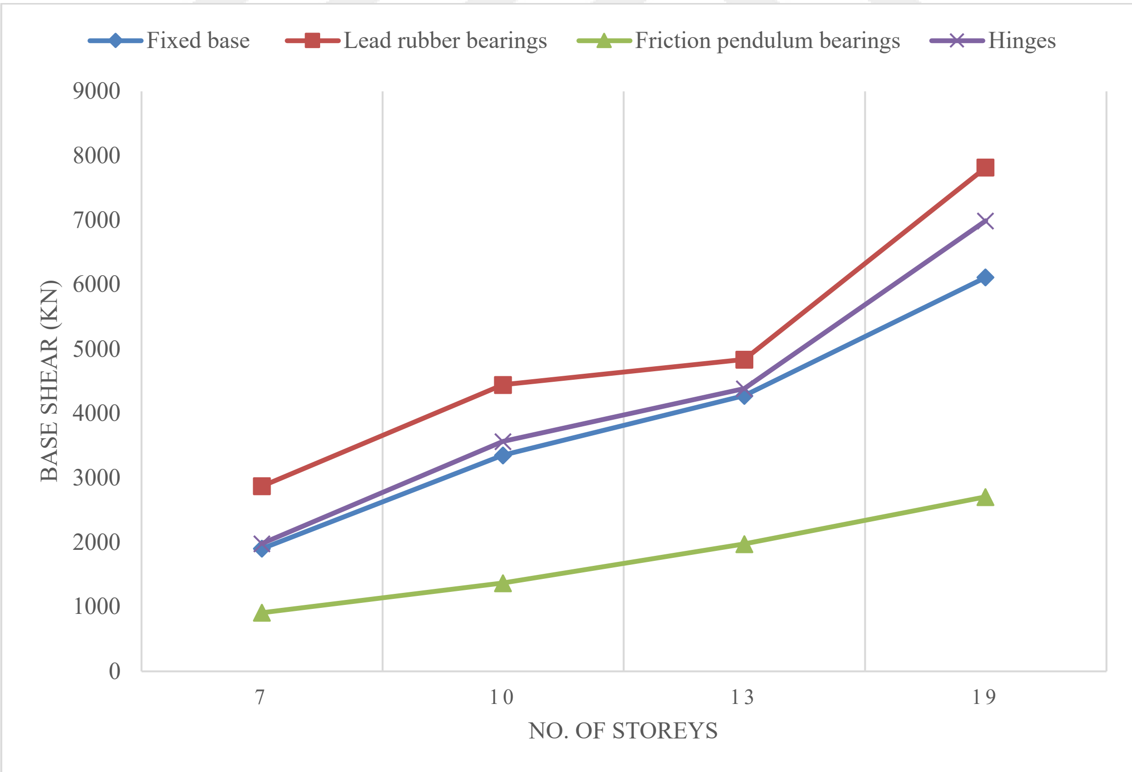



**Figure 4.40:** Maximum Base Shear Bbased on the No. of Storeys and Different Types of Isolators.

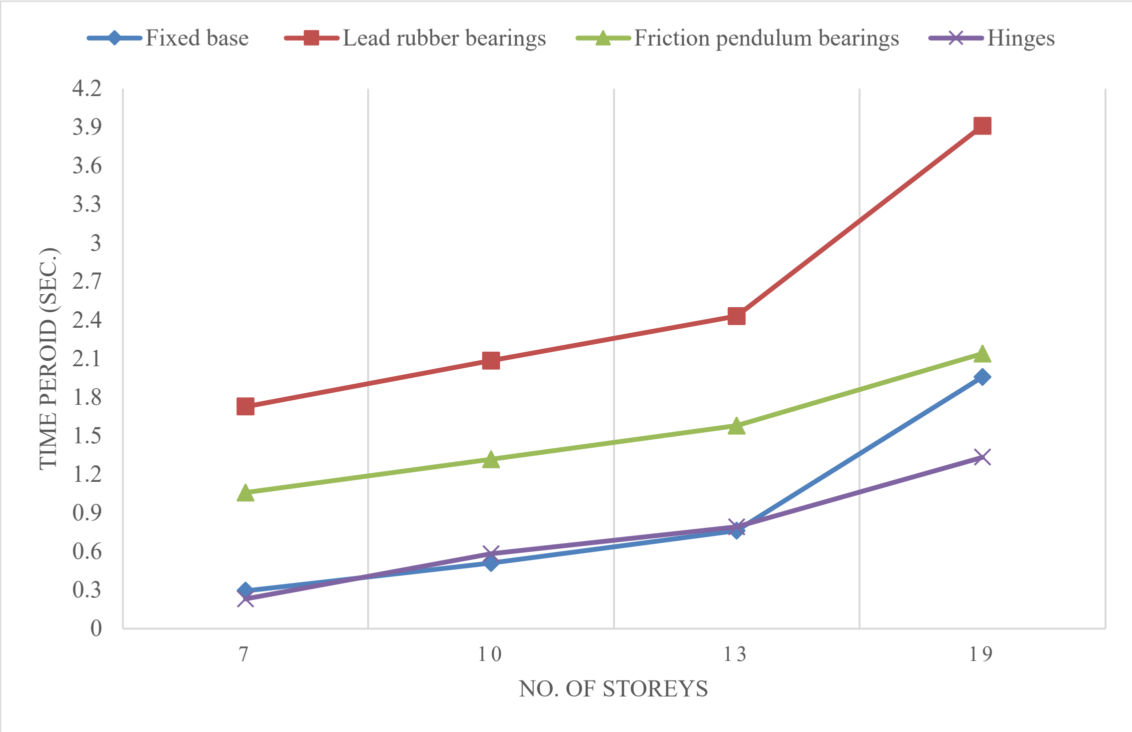



**Figure 4.41 :**Time Period Based on the No. of Storeys and Different Types of Isolators**.**

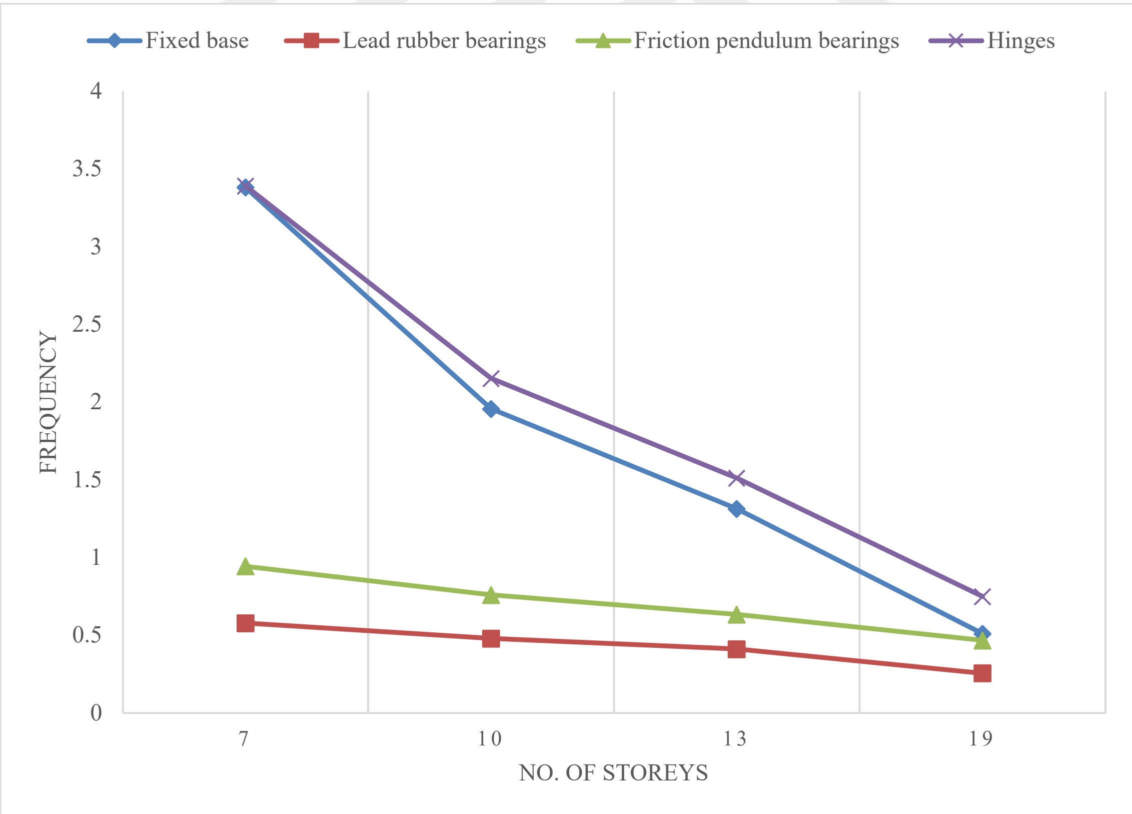



**Figure 4.42:** Frequency Based on the No. of Storeys and Different Types of Isolators.

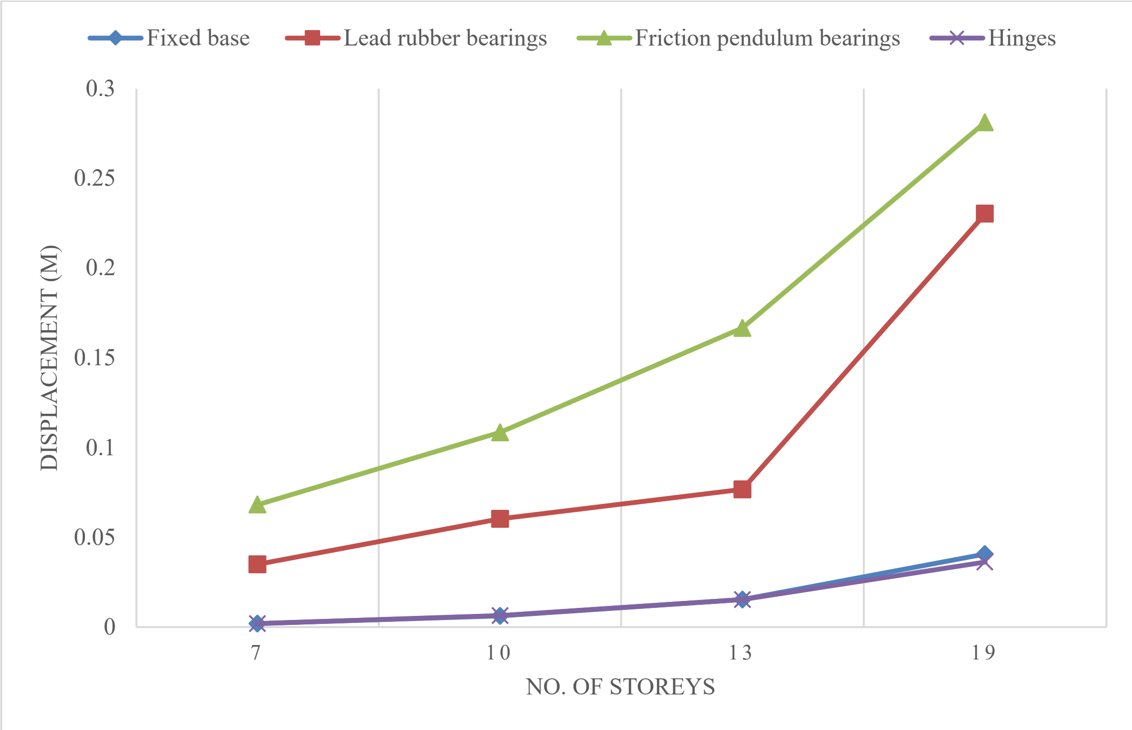



**Figure 4.43 :** Roof Displacements in X Direction Based on the No. of Storeys and Different Types of Isolators.

***The Results When the Storey Height (3.1 m), Bay width (6 m) and no. of Bay=5:***


**Figure 4.44:** Maximum Base Shear Based on the No. of Storeys and Different Types of Isolators.

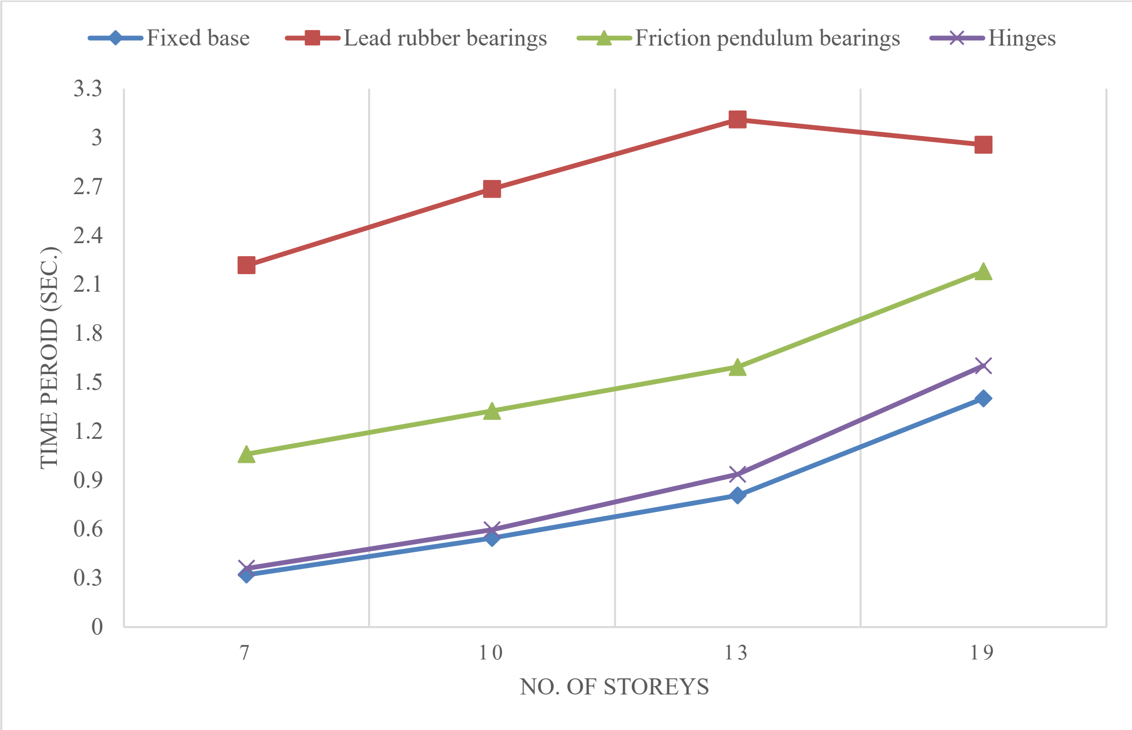



**Figure 4.45:** Time Period Based on the No. of Storeys and Different Types of Isolators.

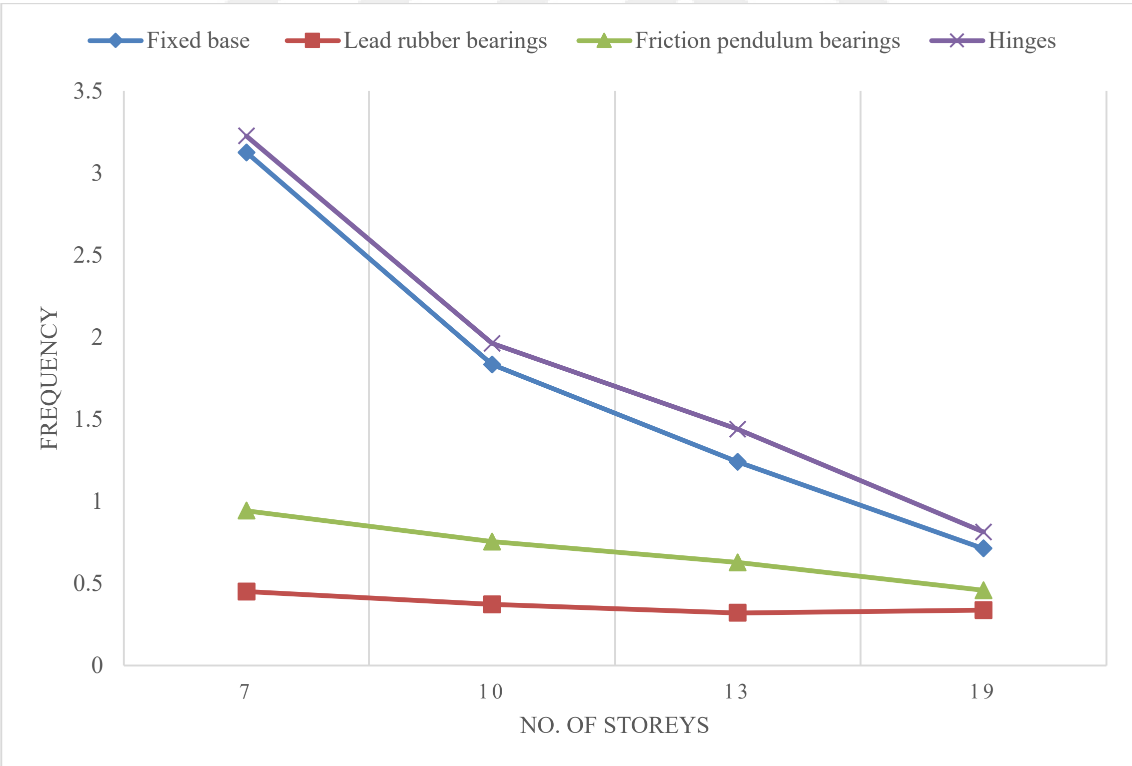



**Figure 4.46:** Frequency Based on the No. of Storeys and Different Types of Isolators

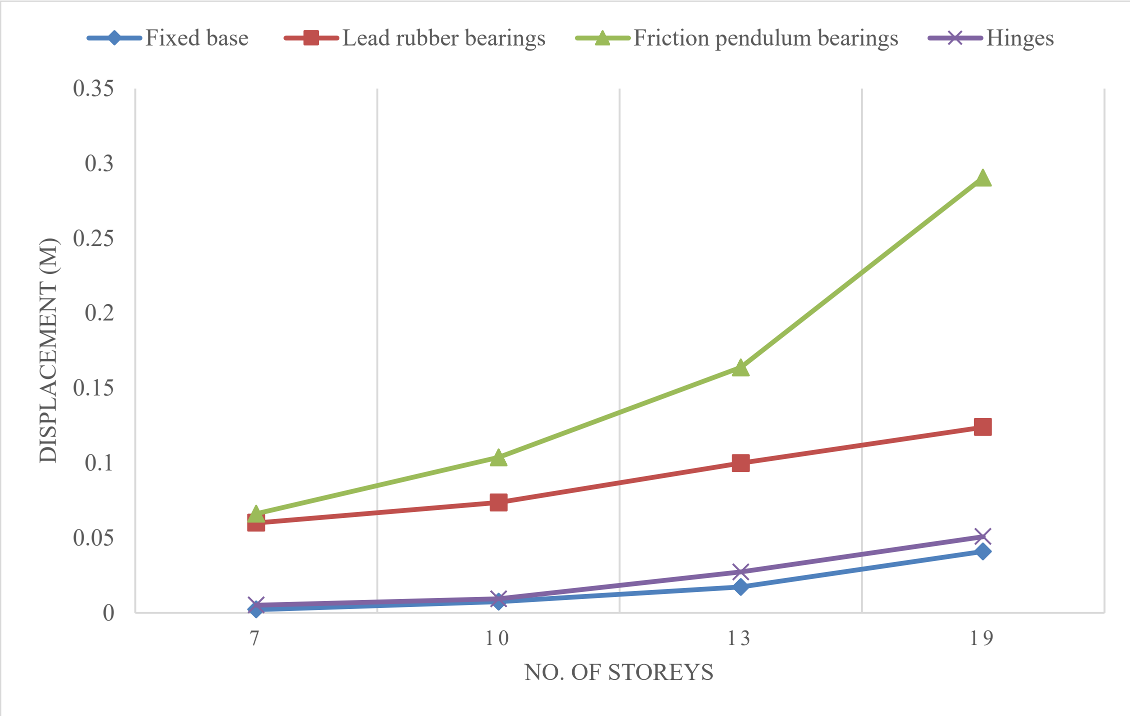



**Figure 4.47:** Roof Displacements in X Direction Based on the No. of Storeys and Different Types of Isolators

#### 4.3.2.3 Storey drift of the buildings RC with shear wall (RCSH)

a. As shown in Figure 4.51, The value of storey drift decreased compared Fixed buildings with Lead rubber bearing and the Friction pendulum system by (20%, & 30%) respectively, While Hinge base increased by (10%) compared Fixed buildings, when the No. of storeys were 7.

b. As shown in Figure 4.55, 4.56, and 4.57, the value of story drift decreased by (21%, & 37%) when the No. of bays increased from 3 to (4, & 5) respectively, when use Fixed building, while its value increased by (10%, & 19%) respectively, when use Lead rubber bearing, its value increased by (29%, & 39%) respectively when use the Friction pendulum system, also its value increased by (24%, and & 44%) respectively, when use Hinge base.

c. As shown in Figure 4.49, 4.52, 4.55, and 4.58, the value of story drift increased by (232%, 700% & 2908%) when the No. of storeys increased from 7 to (10, 13 & 19) respectively, when use Fixed building, while its value increased by (23%, 60% & 268%) respectively, when use Lead rubber bearing, its value increased by (36%, 40%

& 52%) respectively when use the Friction pendulum system, also its value increased by (230%, 807% & 2887%) respectively, when use Hinge base.

d. As shown in Figure 4.49, 4.50, and 4.51, When using shear wall, the value of story drift decreased by (3%, 23%, 1553% & 2620%) when the No. of storeys 7 when use (The Friction pendulum system, Lead rubber bearing, Fixed base, and Hinge base) respectively comparison without shear wall.

e. as shown in Figure 4.52, 4.53, and 4.54, When using shear wall, the value of story drift decreased by (70%, 37%, 1083% & 1309%) when the No. of storeys 7 when use (The Friction pendulum system, Lead rubber bearing, Fixed base, and Hinge base) respectively comparison without shear wall.

f. as shown in Figure 4.55, 4.56, and 4.57, When using shear wall, the value of story drift decreased by (72%, 81%, 554% & 450%) when the No. of storeys 7 when use (The Friction pendulum system, Lead rubber bearing, Fixed base, and Hinge base) respectively comparison without shear wall.

g. as shown in Figure 4.58, 4.59, and 4.60, When using shear wall, the value of story drift decreased by (1034%, 99%, 398% & 450%) when the No. of storeys 7 when use (The Friction pendulum system, Lead rubber bearing, Fixed base, and Hinge base) respectively comparison without shear wall.

***The Results of Storey Drift When the No. of storeys were 7:***

Case 1

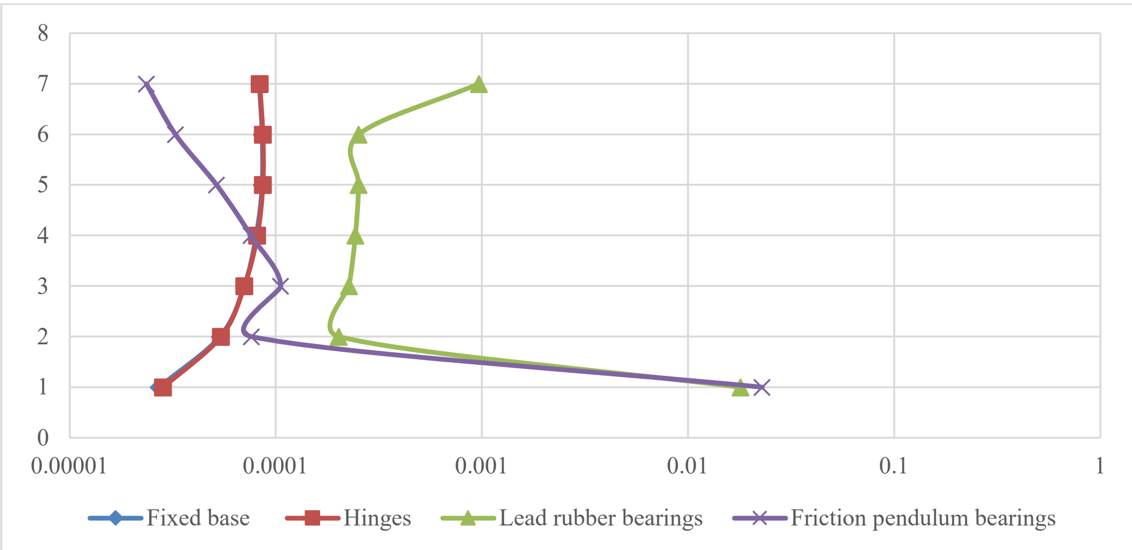



**Figure 4.48**: Storey Drift in X Direction When the No. of Storeys were 7.

Case 2

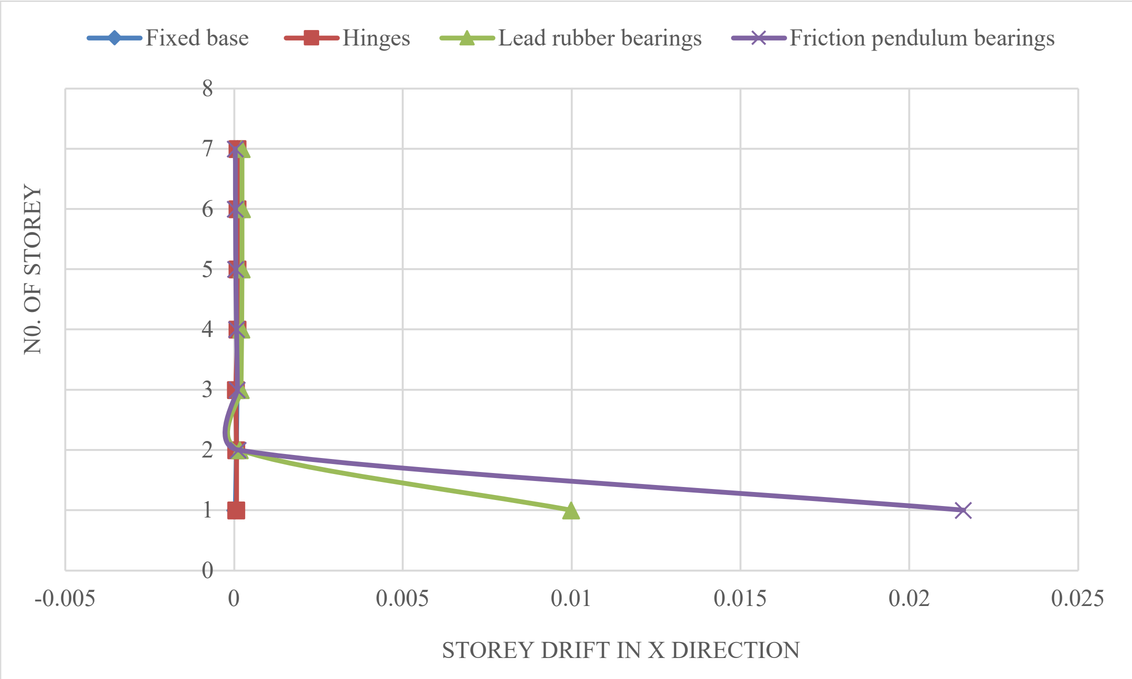



**Figure 4.49:** Storey Drift in X Direction When the No. of Storeys were 7.

Case 3

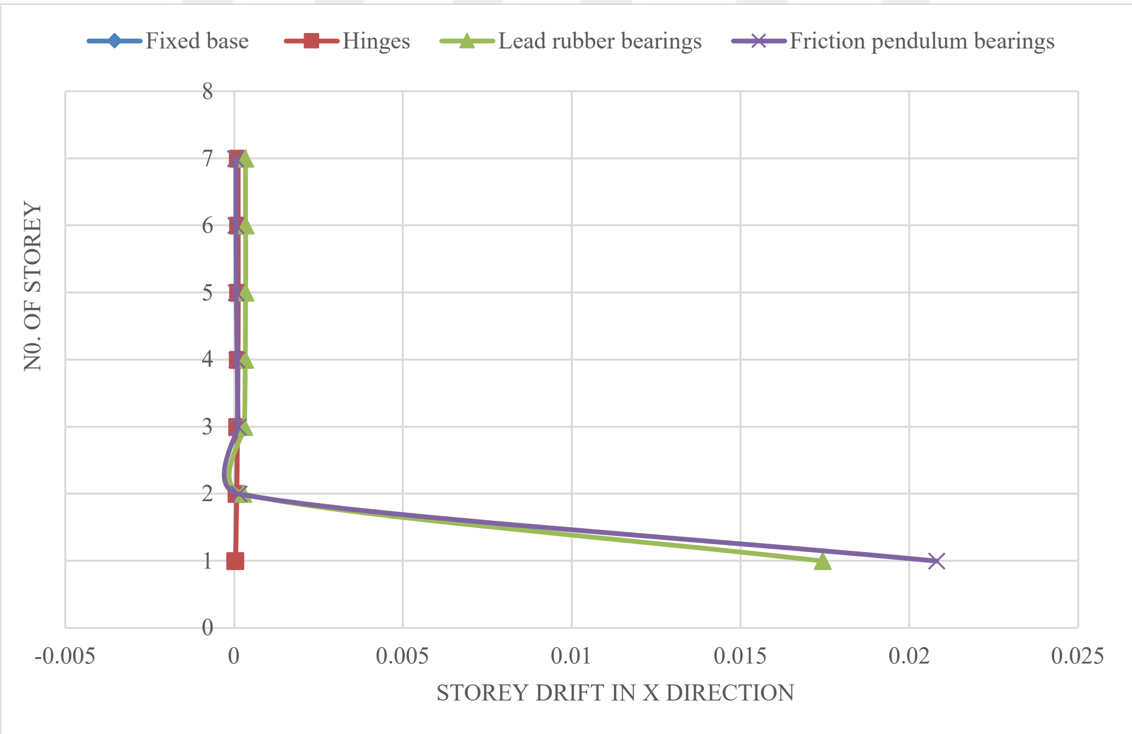



**Figure 4.50:** Storey Drift in X Direction When the No. of Storeys were 7.

***The Results of Storey Drift When the No. of storeys were 10:***

Case 1

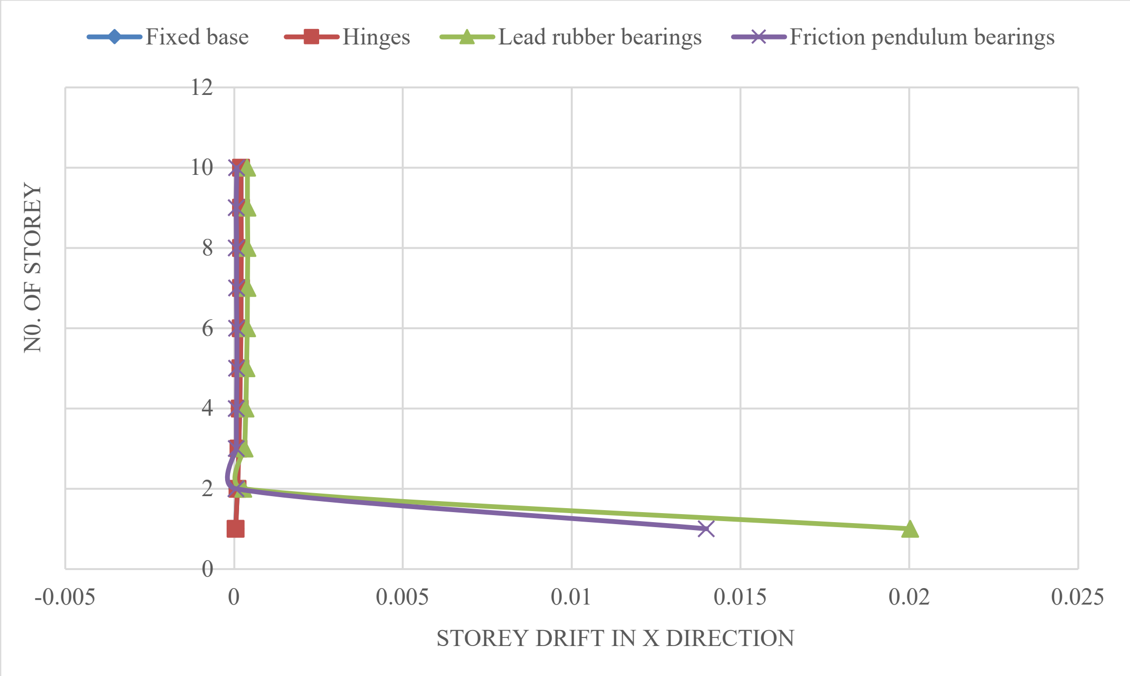



**Figure 4.51:** Storey Drift in X Direction When the No. of Storeys were 10.

Case 2

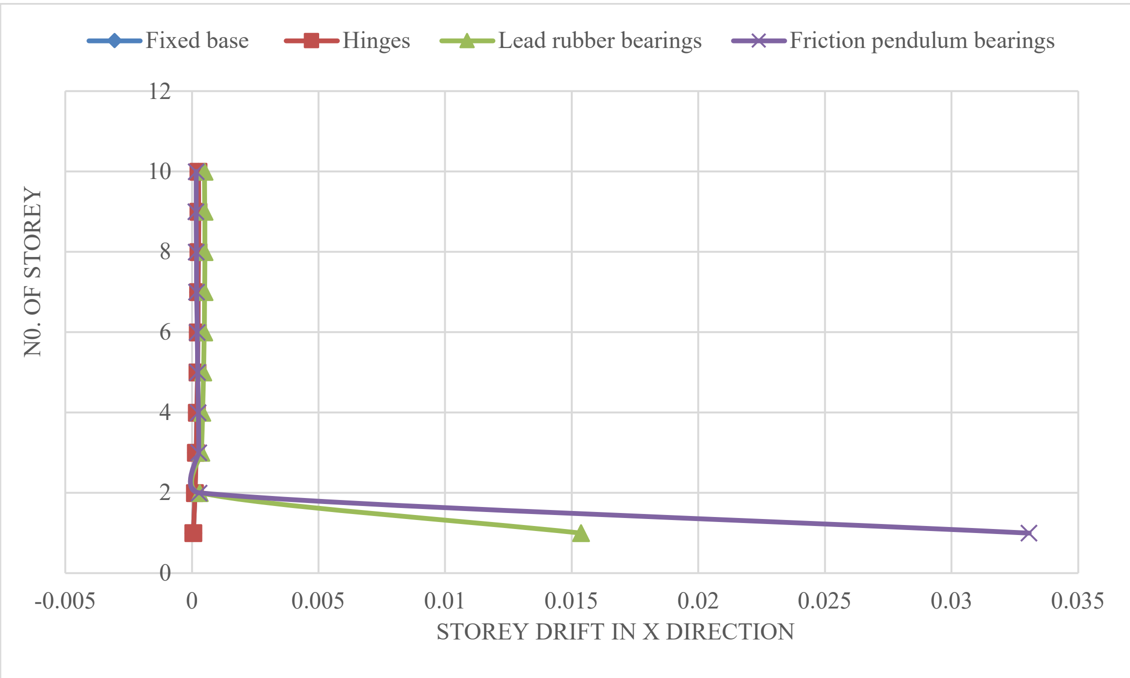



**Figure 4.52:** Storey Drift in X Direction When the No. of Storeys were 10

Case 3

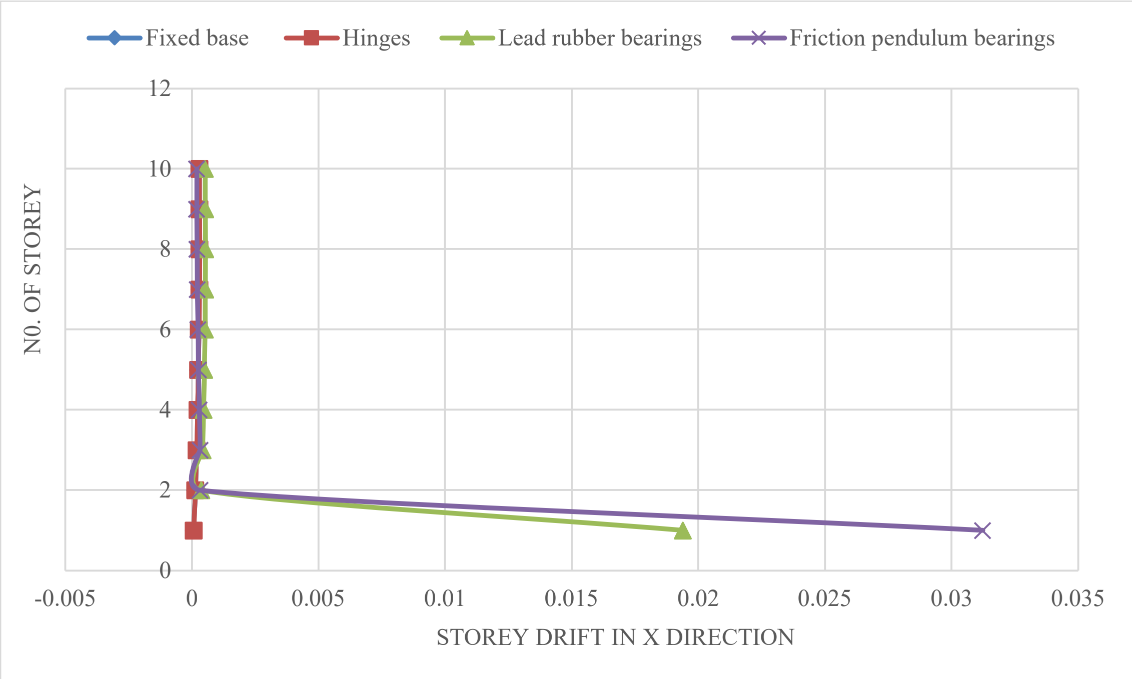



**Figure 4.53:** Storey Drift in X Direction When the No. of Storeys were 10.

***The Results of Storey Drift When the No. of storeys were 13:***

Case 1

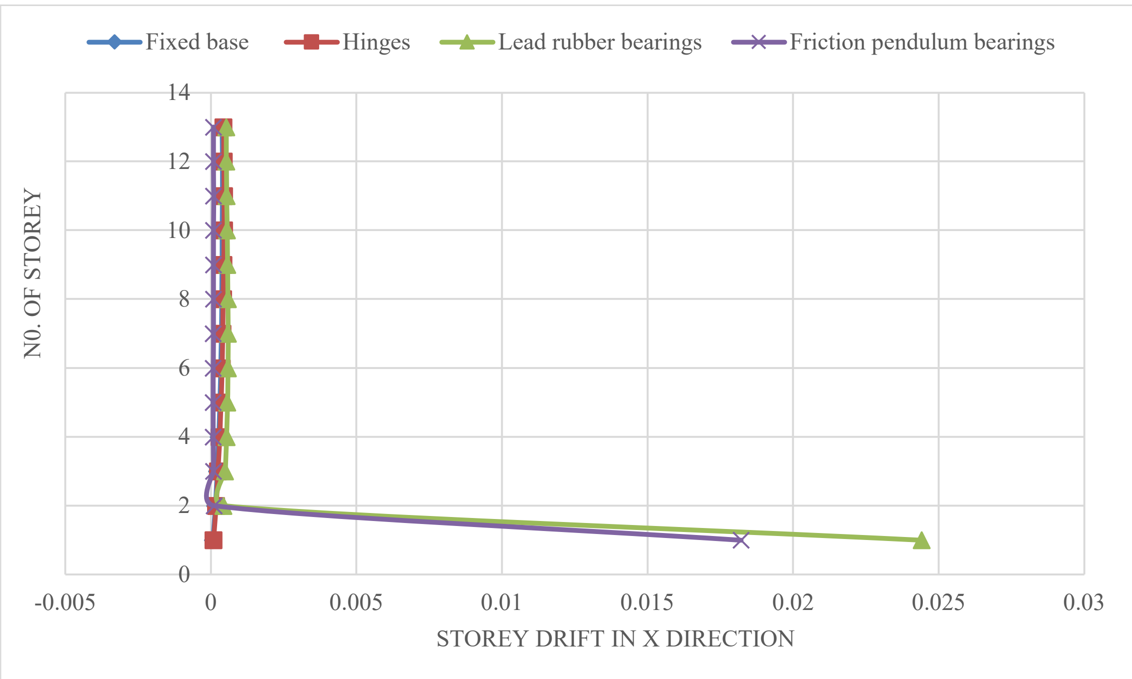



**Figure 4.54:** Storey Drift in X Direction When the No. of Storeys were 13.

Case 2

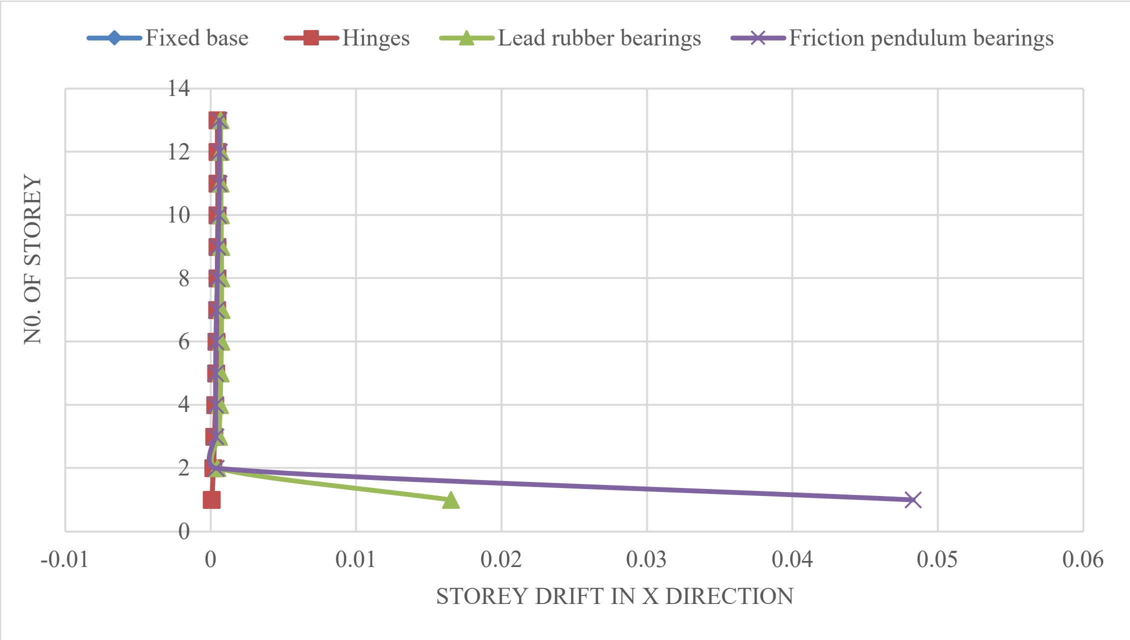



**Figure 4.55:** Storey Drift in X Direction When the No. of Storeys were 13.

Case 3

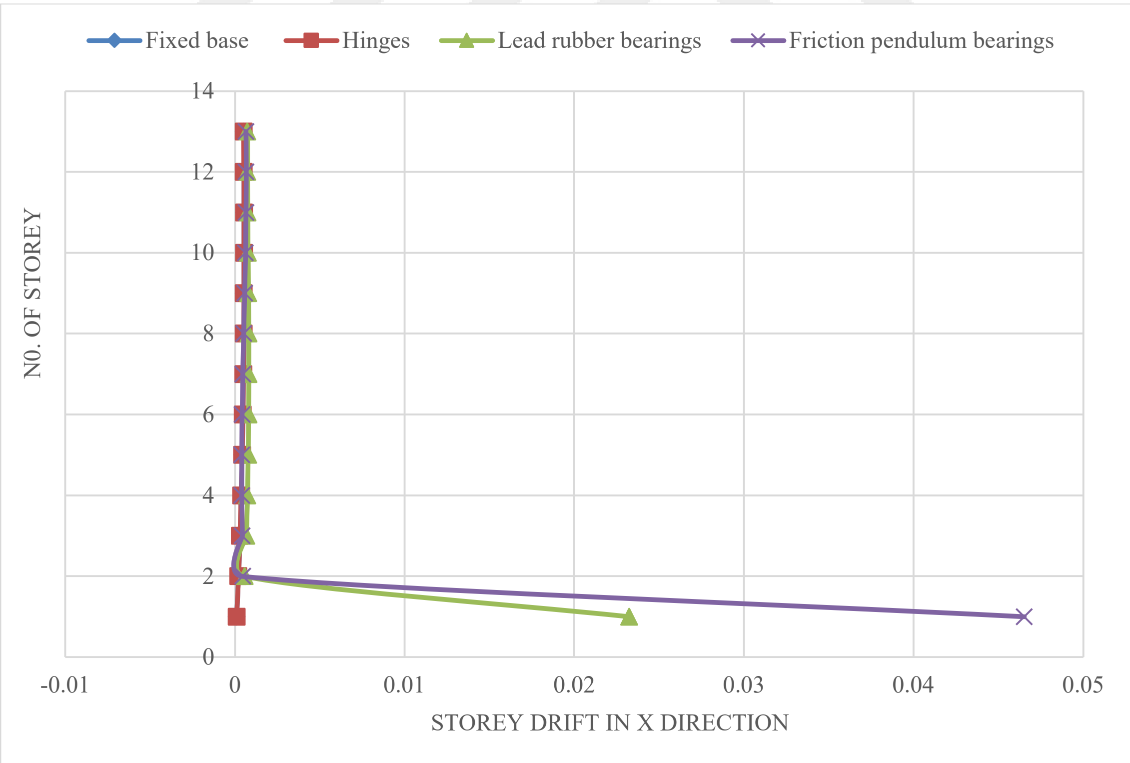



**Figure 4.56:** Storey Drift in X Direction When the No. of Storeys were 13**.**

***The Results of Storey Drift When the No. of storeys were 19:***

Case 1

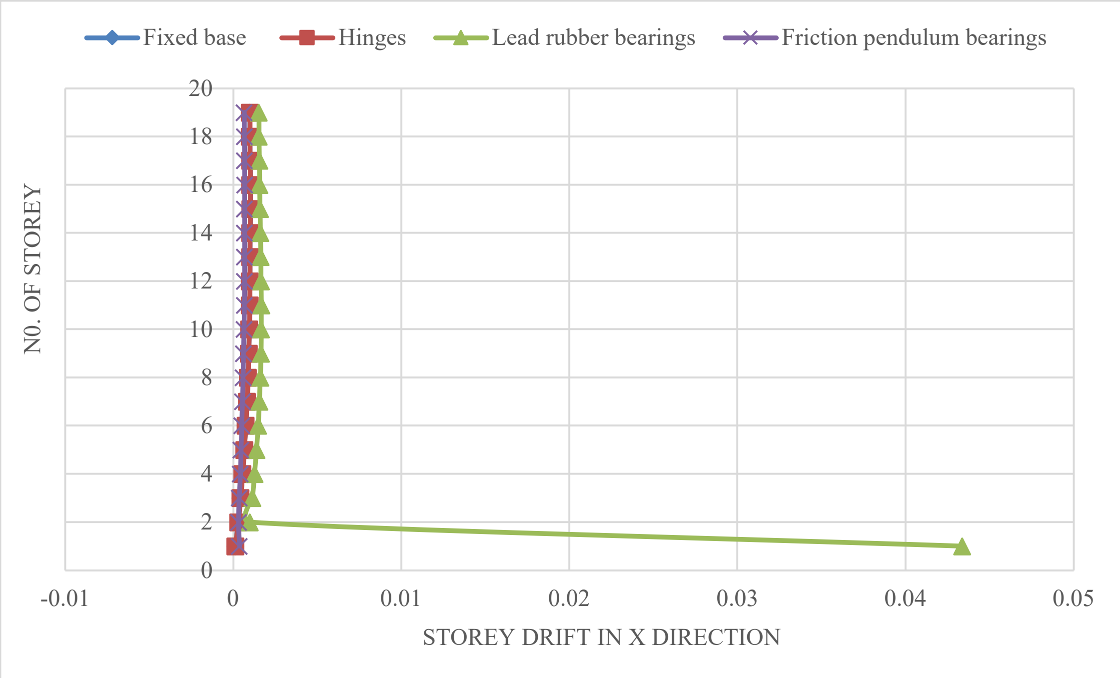



**Figure 4.57:** Storey Drift in X Direction When the No. of Storeys were 19.

Case 2

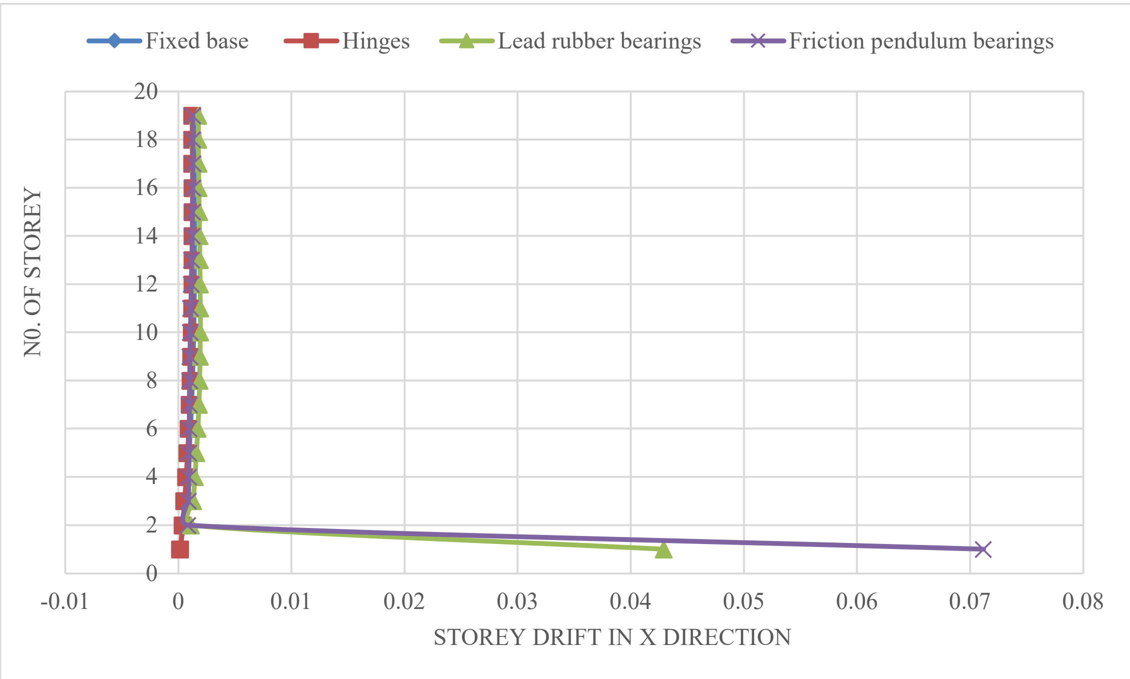



**Figure 4.58:** Storey Drift in X Direction When the No. of Storeys were 19.

Case 3

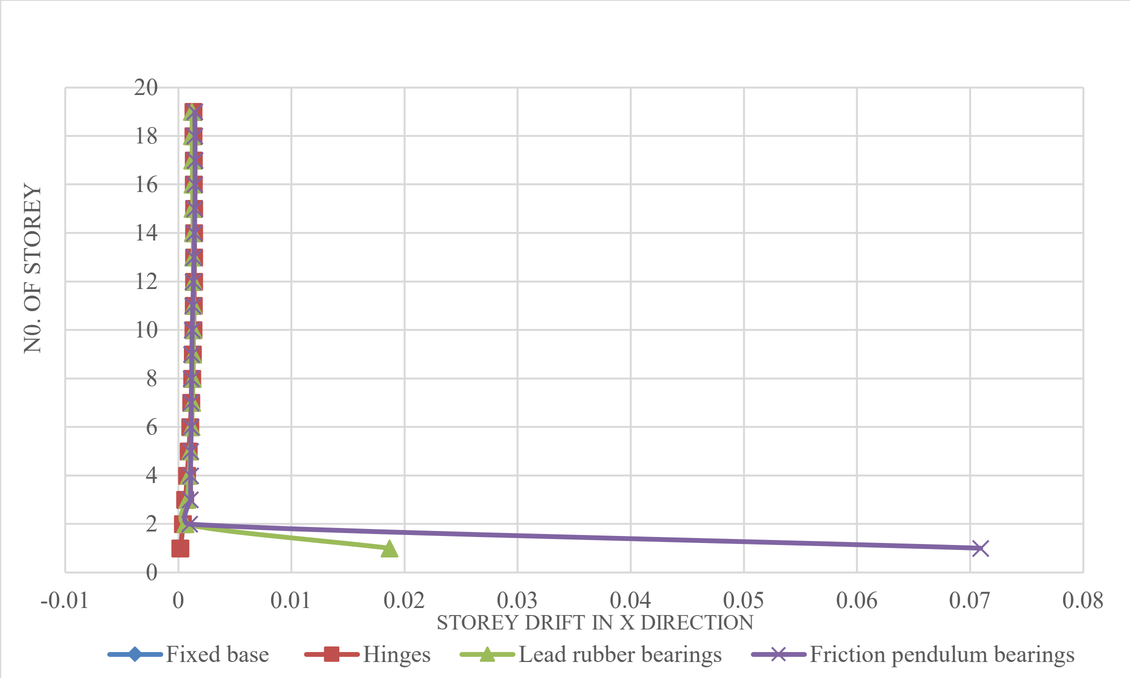



**Figure 4.59:** Storey Drift in X Direction When the No. of Storeys were 19.

## 4.4 MODELING RESULTS OF BUILDINGS STEEL CONSTRUCTION

The steel construction of skyscrapers, bridges, tunnels, towers, industrial buildings, and road barriers is common in the construction industry. Structural steels show low weight, high strength, ease of use, and homogeneity. Structural steels offer strength, ductility, weldability, and resistance against corrosion. the effect of steel building when the earthquake happens is at the top (last stories), higher than the first, and the large drift is at the rubber and friction support in the first story.

### 4.4.1 Modeling Results Based on the No. of Storeys and Various Isolators (The Friction Pendulum System, Lead Rubber Bearing, and Hinge Base)

The value of the base shear, Time period, frequency, and displacements increased or decreased with various isolators (The Friction pendulum system, Lead rubber bearing, and Hinge base) compared to fixed buildings, as shown below:

a. As shown in Figure 4.61, The value of base shear increased compared Fixed buildings with Lead rubber bearing and Hinge base by (22%, & 2%) respectively, While the Friction pendulum system decreased by (71%) compared Fixed buildings, when the No. of storeys were 7. while when the No. of storeys 19 the value of base shear increased compared Fixed buildings with Lead rubber bearing and Hinge base by (35%, & 5%) respectively, While the Friction pendulum system decreased by (74%) compared Fixed buildings.

b. As shown in Figure 4.62, the value of time period increased compared Fixed buildings with (Lead rubber bearing, the Friction pendulum system, and Hinge base) by (148%, 36%, & 22%) respectively, when the No. of storeys were 7. while when the No. of storeys 19 the value of time period increased compared Fixed buildings with (Lead rubber bearing, the Friction pendulum system, and Hinge base) by (64%, 21%, & 6%) respectively.
c. As shown in Figure 4.63, the value of Frequency decreased compared Fixed buildings with (Lead rubber bearing, the Friction pendulum system, and Hinge base) by (60%, 36%, & 22%) respectively, when the No. of storeys were 7. while when the No. of storeys 19 the value of Frequency decreased compared Fixed buildings with (Lead rubber bearing, the Friction pendulum system, and Hinge base) by (40%, 17%, & 5%) respectively.
d. As shown in Figure 4.64, the value of displacements increased compared Fixed buildings with (Lead rubber bearing, the Friction pendulum system, and Hinge base) by (184%, 272%, &46%) respectively, when the No. of storeys were 7. while when the No. of storeys 19 the value of displacements increased compared Fixed buildings with (Lead rubber bearing, the Friction pendulum system, and Hinge base) by (122%, 171%, & 9%) respectively.

The value of the base shear, Time period and displacements increased as the No. of storeys increased, while the value of frequency decreased as the No. of storeys increased. The increase of base shear due to increase the height of building, also the increase lateral displacements of the buildings, as shown below:

a. As shown in Figure 4.61, the value of base shear increased by (38%, 95% & 125%) when the No. of storeys increased from 7 to (10, 13 & 19) respectively, when use Fixed building, while its value increased by (27%, 42% & 150%) respectively, when use Lead rubber bearing, its value increased by (6%, 30% & 96%) respectively when use the Friction pendulum system, also its value increased by (48%, 102% & 125 %) respectively, when use Hinge base.

b. As shown in Figure 4.62, the value of time period increased by (43%, 88 % & 183 %) when the No. of storeys increased from 7 to (10, 13 & 19) respectively, when use Fixed building, while its value increased by (23 %, 45 % & 87 %) respectively, when use Lead rubber bearing, its value increased by (30 %, 59 % & 120 %) respectively when use the Friction pendulum system, also its value increased by (34 %, 69 % & 134 %) respectively, when use Hinge base.

c. As shown in Figure 4.63, the value of Frequency decreased by (30%, 46% & 64%) when the No. of storeys increased from 7 to (10, 13 & 19) respectively, when use Fixed building, while its value decreased by (18%, 31% & 46%) respectively, when use Lead rubber bearing, its value decreased by (22%, 37% & 54%) respectively when use the Friction pendulum system, also its value decreased by (25 %, 41 % & 57 %) respectively, when use Hinge base.

d. As shown in Figure 4.64, the value of displacements increased by (99%, 290 % & 579 %) when the No. of storeys increased from 7 to (10, 13 & 19) respectively, when use Fixed building, while its value increased by (100 %, 139 % & 431 %) respectively, when use Lead rubber bearing, its value increased by (58 %, 133 % & 380 %) respectively when use the Friction pendulum system, also its value increased by (118 %, 241 % & 391 %) respectively, when use Hinge base.

***The Results When the Storey Height (3.1 m), Bay width (6 m) and no. of Bay = 5***

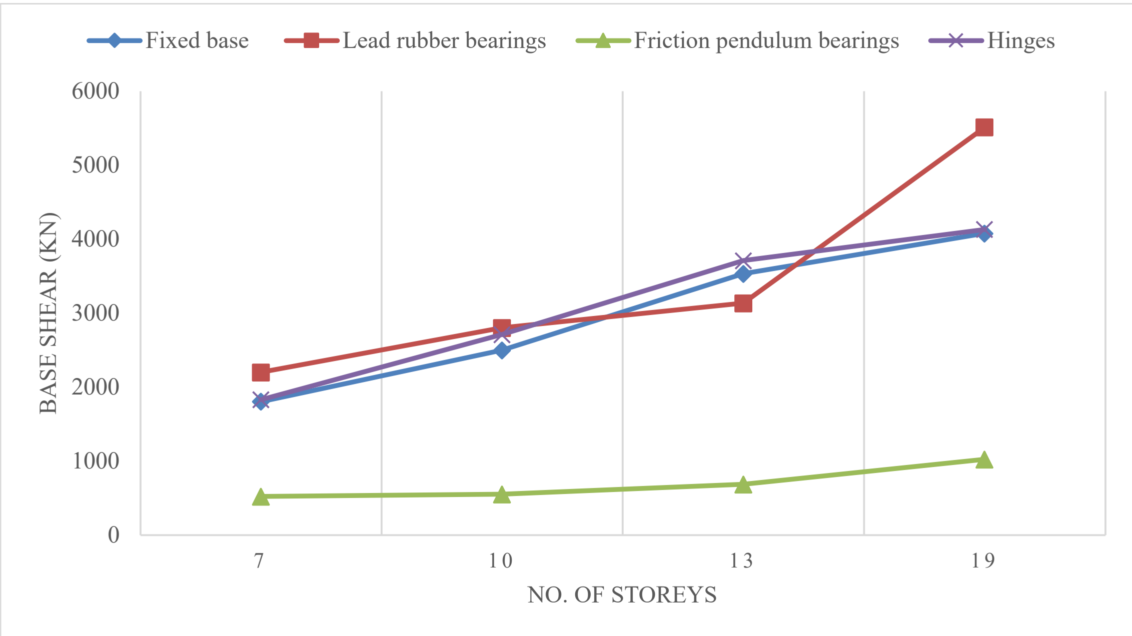



**Figure 4.60:** Maximum Base Shear Based on the No. of Storeys and Different Types of Isolators.

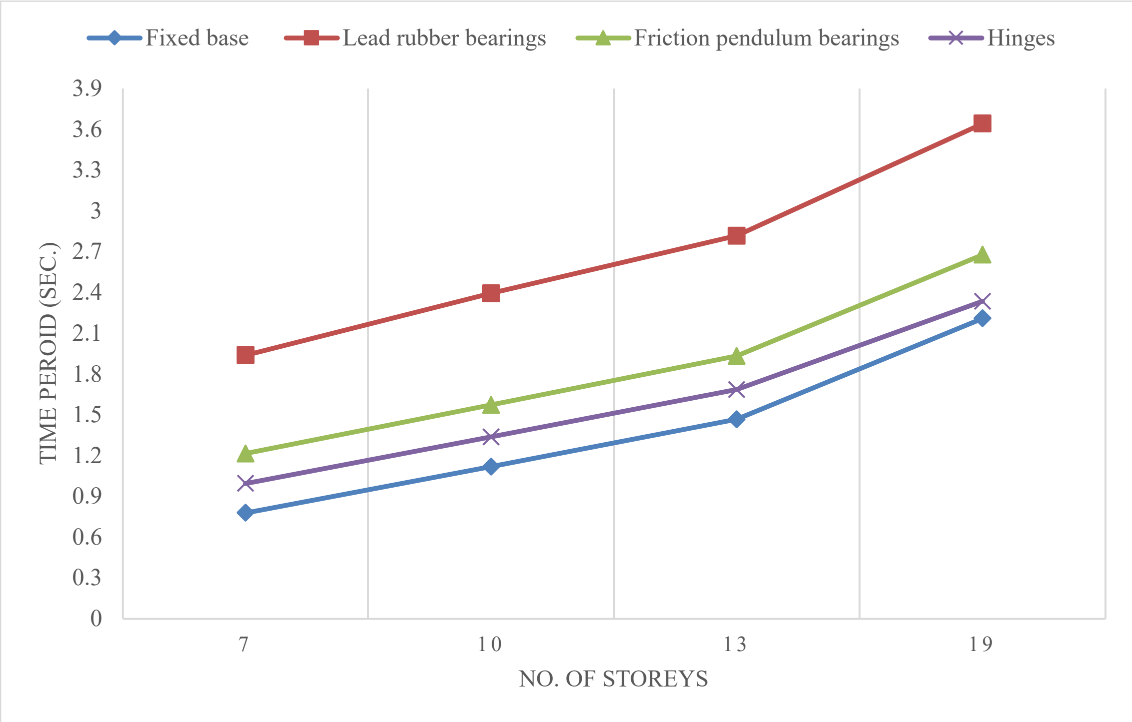



**Figure 4.61:** Time Period Based on the No. of Storeys and Different Types of Isolators.

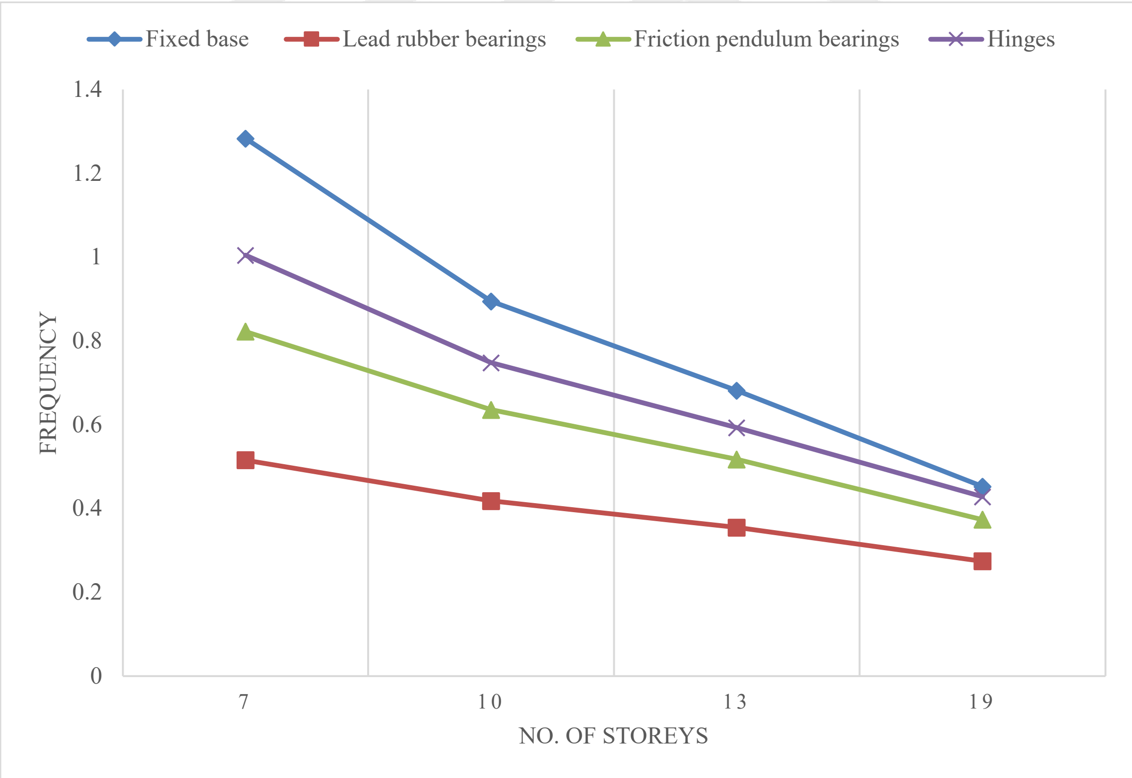



**Figure 4.62:** Frequency Based on the No. of Storeys and Different Types of Isolators


**Figure 4.63:** Roof Displacements in X Direction Based on the No. of Storeys and Different Types of Isolators.

### 4.4.2 Storey Drift of the Buildings Steel Construction

a. As shown in Figure 4.65, and 4.68, The value of storey drift increased compared Fixed buildings with Lead rubber bearing and the Friction pendulum system by (682%, & 780%) respectively, While Hinge base decreased by (5 %) compared Fixed buildings, when the No. of storeys were 7. while when the No. of storeys 19 the value of story drift increased compared Fixed buildings with Lead rubber bearing and Friction pendulum system by (86%, and 125), While the Hinge base decreased by (6%) respectively, compared by Fixed buildings.
b. As shown in Figure 4.66, and 4.67, The value of storey drift increased compared Fixed buildings with the Friction pendulum system, Lead rubber bearing, and Hinge base by (42%, & 154%, and 113%) respectively, when the No. of storeys were 10. while when the No. of storeys 13 the value of story drift increased compared Fixed buildings with Hinge base and Friction pendulum system by (6%, and 72), While the Lead rubber bearing decreased by (36%) respectively, compared by Fixed buildings.
c. As shown in Figure 4.65, 4.66, 4.67, and 4.68, the value of story drift increased by (19%, 56% & 70%) when the No. of storeys increased from 7 to (10, 13 & 19)

respectively, when use Fixed building, while its value decreased by (61%, 87% &, and 59%) respectively, when use Lead rubber bearing, its value decreased by (92%, 69% & 56%) respectively when use the Friction pendulum system, also its value increased by (163%, 71% & 66%) respectively, when use Hinge base.

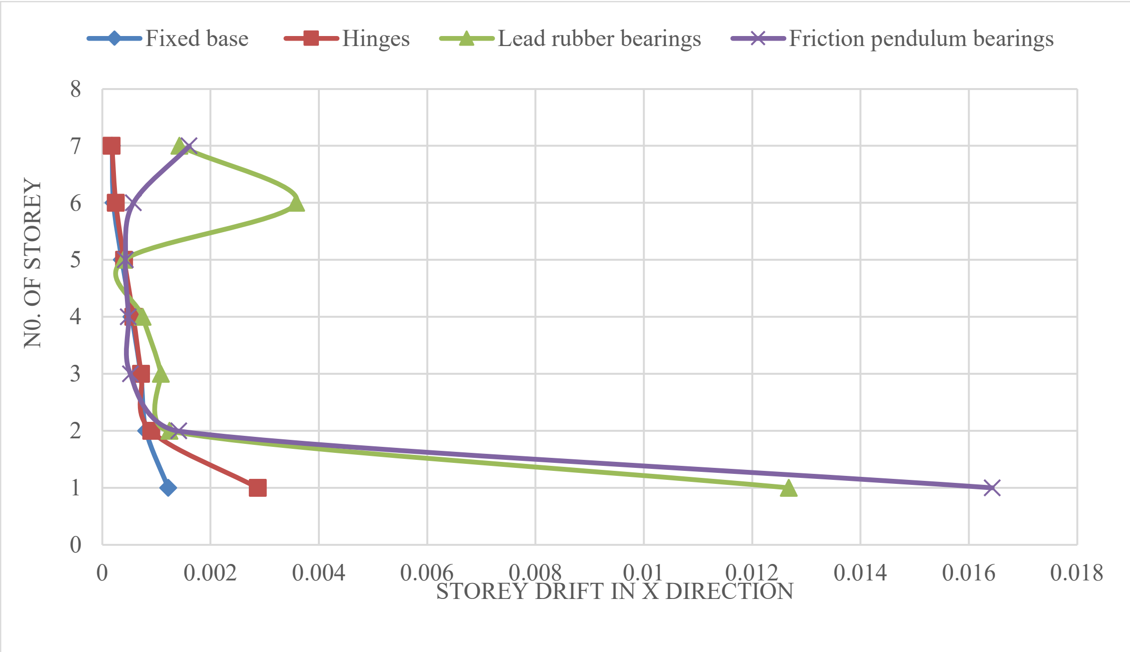



**Figure 4.64:** Storey Drift in X Direction When the No. of Storeys were 7.

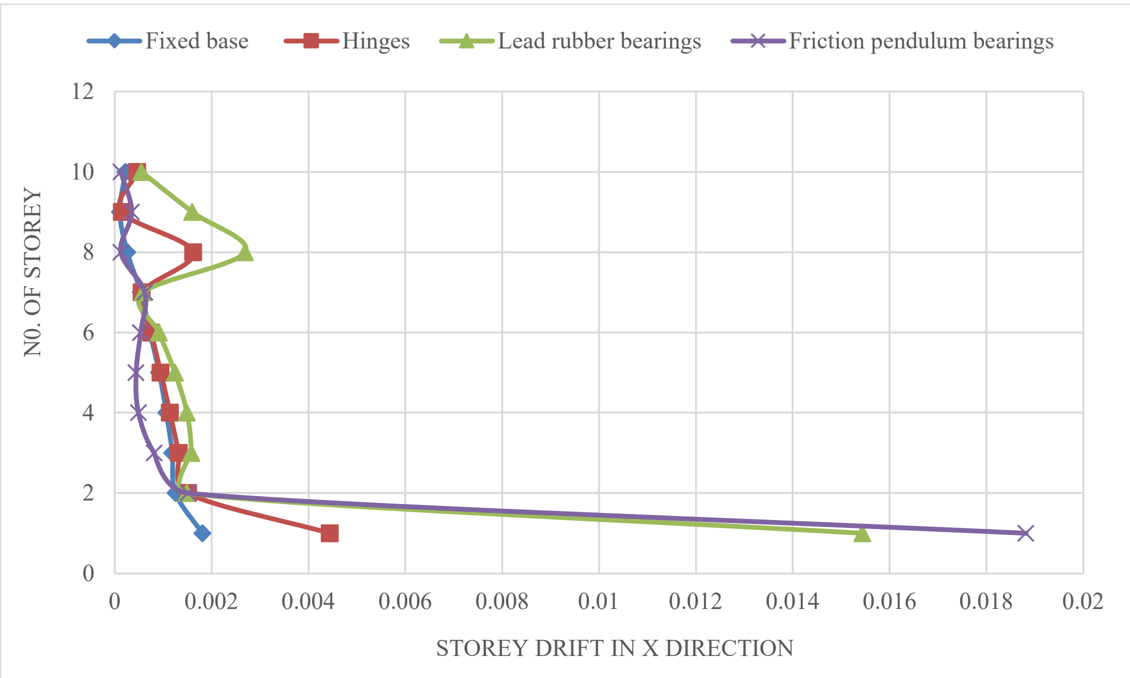



**Figure 4.65:** Storey Drift in X Direction When the No. of Storeys were 10.

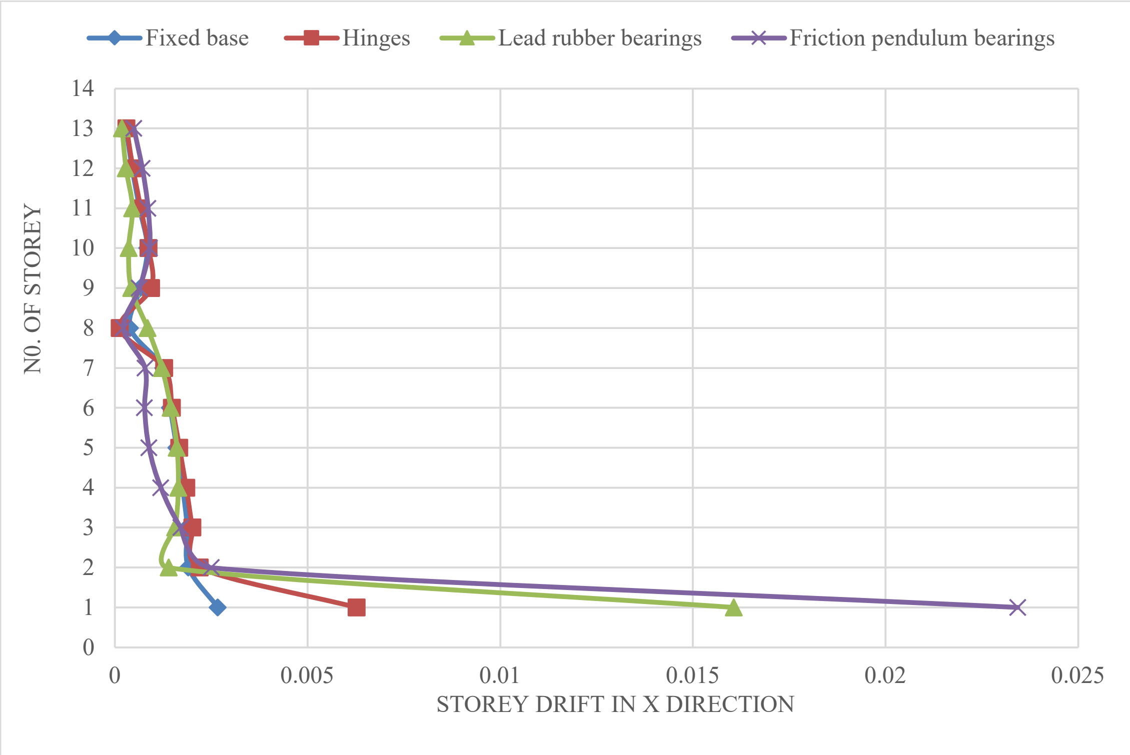



**Figure 4.66:** Storey Drift in X Direction When the No. of Storeys were 13.

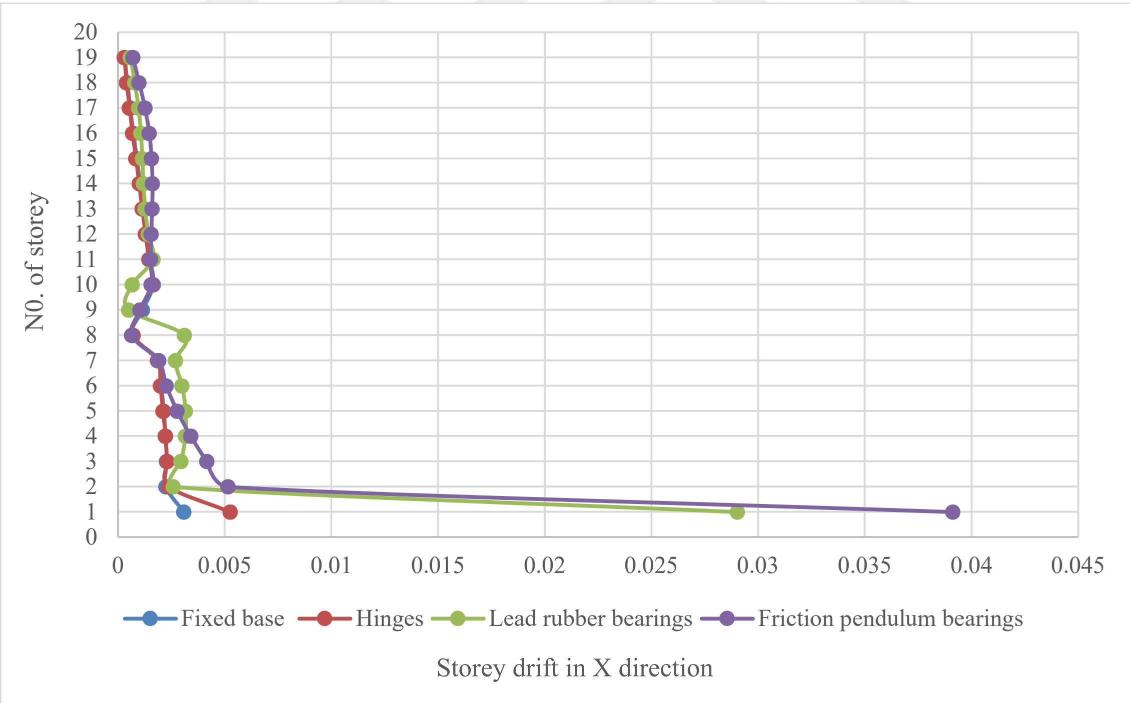



**Figure 4.67:** Storey Drift in X Direction When the No. of Storeys were 19.

### 4.5 MODELING RESULTS OF BUILDINGS HYBRID CONSTRUCTION (25% RC, AND 75% STEEL)

Hybrid can be engineered to exhibit high strength, high stiffness, and high toughness. hybrid structures have been used increasingly in various engineering applications. where the hybrid system is very recommended system of multi-story building against seismic loading because increased the ductility and reduce the weight of structure. the concrete reduces the effect of drift at last stories so made the first 25 % stories from concrete and 75 % the remain stories steel.

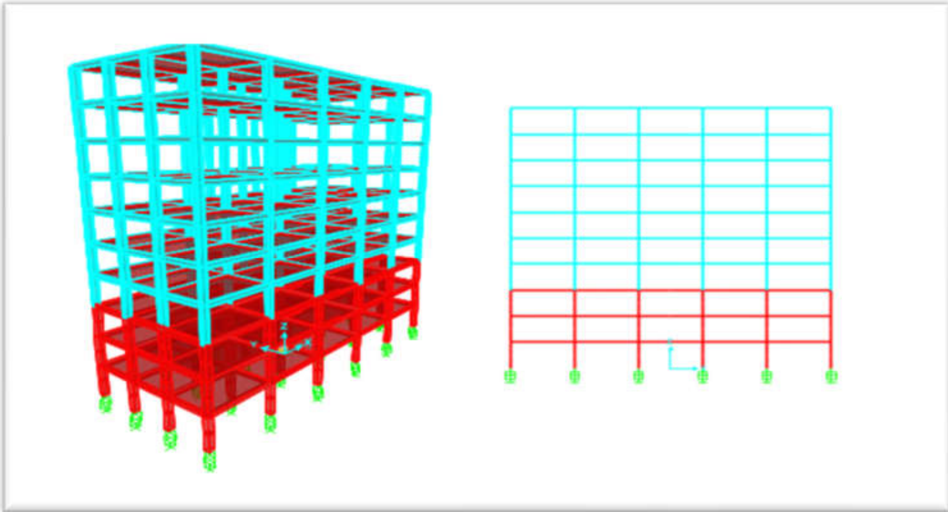


**Figure 4.68:** 2D & 3D Model of 10 Storey with Hybrid Construction**.**

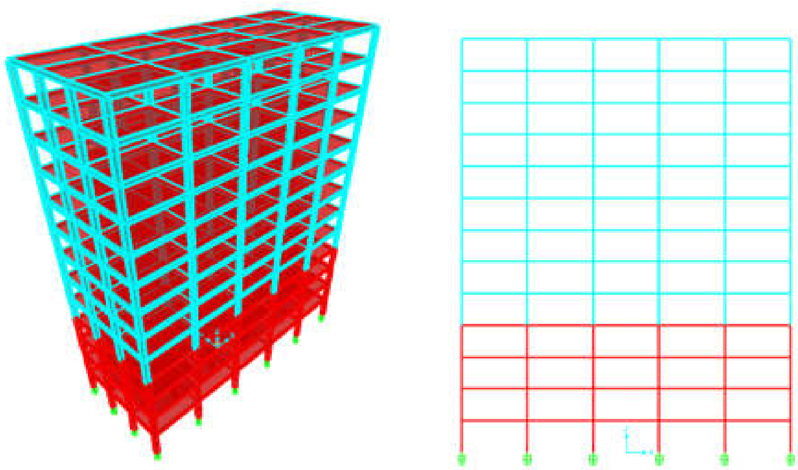


**Figure 4.69:** 2D & 3D Model of 13 Storey with Hybrid Construction

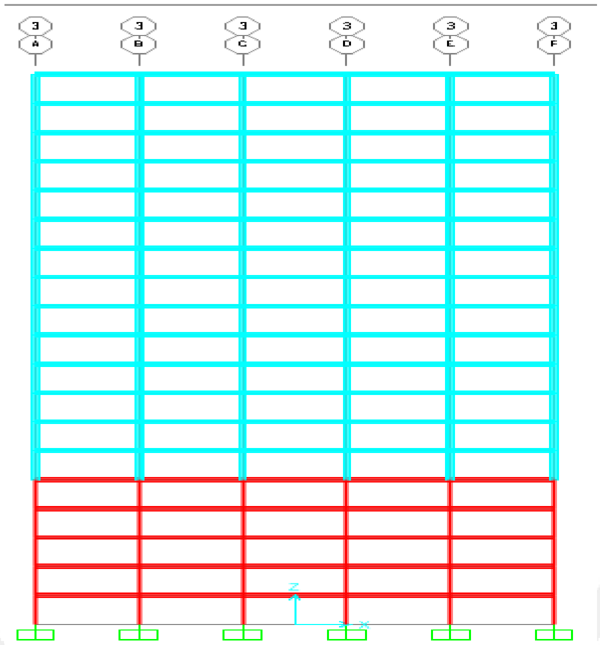


**Figure 4.70:** 2D Model of 19 Storeys with Hybrid Construction.

### 4.5.1 Modeling Results Based on the No. of Storeys and Various Isolators (The Friction Pendulum System, Lead Rubber Bearing, and Hinge Base)

The value of the base shear, Time period, frequency, and displacements increased or decreased with various isolators (The Friction pendulum system, Lead rubber bearing, and Hinge base) compared to fixed buildings, as shown below:

a. As shown in Figure 4.72, The value of base shear decreased compared Fixed buildings with Lead rubber bearing and the Friction pendulum system by (10%, & 78%) respectively, While Hinge base increased by (10%) compared Fixed buildings, where the No. of storeys were 10, and when the No. of storeys were 19, The value of base shear increased compared Fixed buildings with Lead rubber bearing and Hinge base by (40%, & 10%) respectively, While the Friction pendulum system decreased by (76%) compared Fixed buildings,
b. As shown in Figure 4.73, the value of time period increased in comparison to Fixed buildings with (Lead rubber bearing, the Friction pendulum system, and Hinge base) by (121%, 40%, & 16%) when the No. of storeys were 10, and when the No. of storeys were 19, the value of time period increased by (76%, 24%, & 10%) respectively.

c. As shown in Figure 4.74, the value of Frequency reduced by 54%, 28%, and 15% for Lead rubber bearings, friction pendulum systems, and hinge bases, respectively, when the number of storeys were ten, and it decreased by 43%, 19%, and 7% when the number of storeys were 19.
d. As shown in Figure 4.75, the value of displacements increased compared Fixed buildings with (Lead rubber bearing, the Friction pendulum system, and Hinge base) by (88%, 132%, &21%) respectively, when the No. of storeys were 13, and it increased (118%, 138 %, &20%) respectively, when the No. of storeys were 19.

The value of the base shear, Time period and displacements increased as the No. of storeys increased, while the value of frequency decreased as the No. of storeys increased. The increase of base shear due to increase the height of building, also the increase lateral displacements of the buildings, as shown below:

a. As shown in Figure 4.72, the value of base shear increased by (32%, & 87%) when the No. of storeys increased from 10 to (13 & 19) respectively, when use Fixed building, while its value increased by (54%, & 191%) respectively, when use Lead rubber bearing, its value increased by (30%, & 108%) respectively when use the Friction pendulum system, also its value increased by (6%, & 83 %) respectively, when use Hinge base.
b. As shown in Figure 4.73, the value of time period increased by (32%, & 94 %) when the No. of storeys increased from 10 to (13 & 19) respectively, when use Fixed building, while its value increased by (17%, & 54 %) respectively, when use Lead rubber bearing, its value increased by (24 %, & 73 %) respectively when use the Friction pendulum system, also its value increased by (27 %, & 76 %) respectively, when use Hinge base.
c. As shown in Figure 4.74, the value of Frequency decreased by (24%, & 48%) when the No. of storeys increased from 10 to (13, & 19) respectively, when use Fixed building, while its value decreased by (15%, & 35%) respectively, when use Lead rubber bearing, its value decreased by (19%, & 42%) respectively when use the Friction pendulum system, also its value decreased by (22 %, & 43 %) respectively, when use Hinge base.

d. As shown in Figure 4.75, the value of displacements increased by (3784 %, & 10412%) when the No. of storeys increased from 10 to (13, & 19) respectively, when use Fixed building, while its value increased by (126 %, & 610 %) respectively, when use Lead rubber bearing, its value increased by (72 %, & 376 %) respectively when use the Friction pendulum system, also its value increased by (550 %, & 1650%) respectively, when use Hinge base.

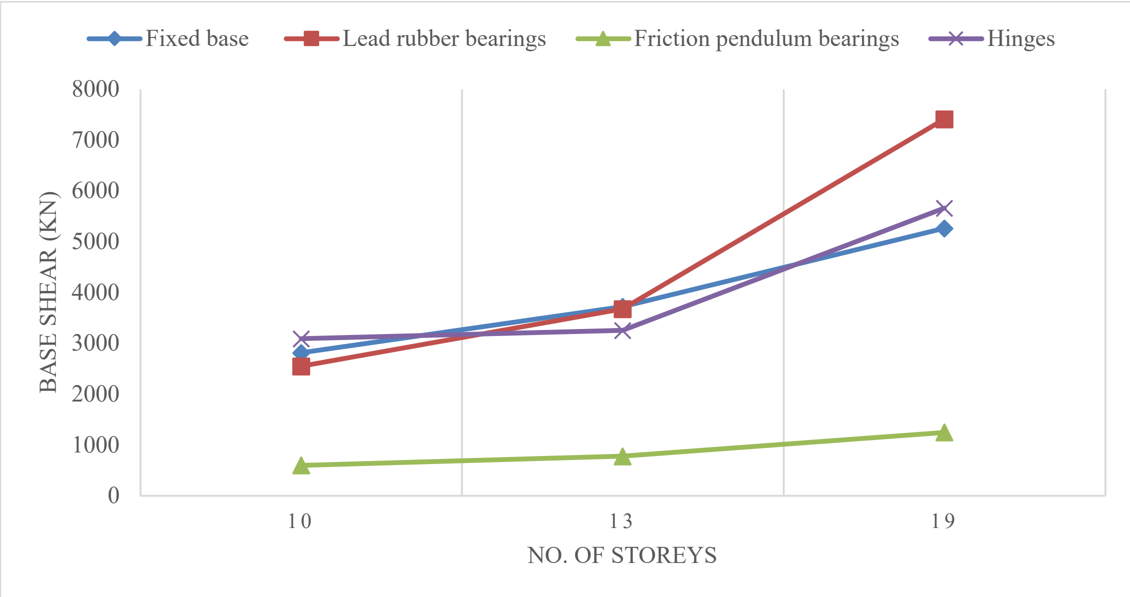



**Figure 4.71:** Maximum Base Shear Based on the No. of Storeys and Different Types of Isolators**.**

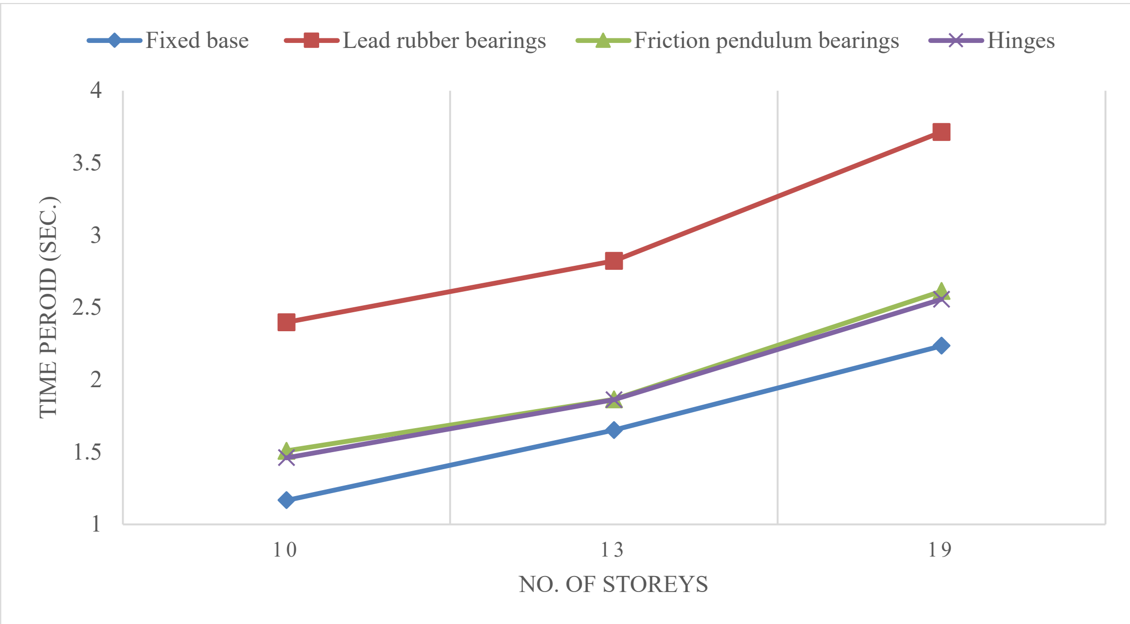



**Figure 4.72:** Time Period Based on the No. of Storeys and Different Types of Isolators

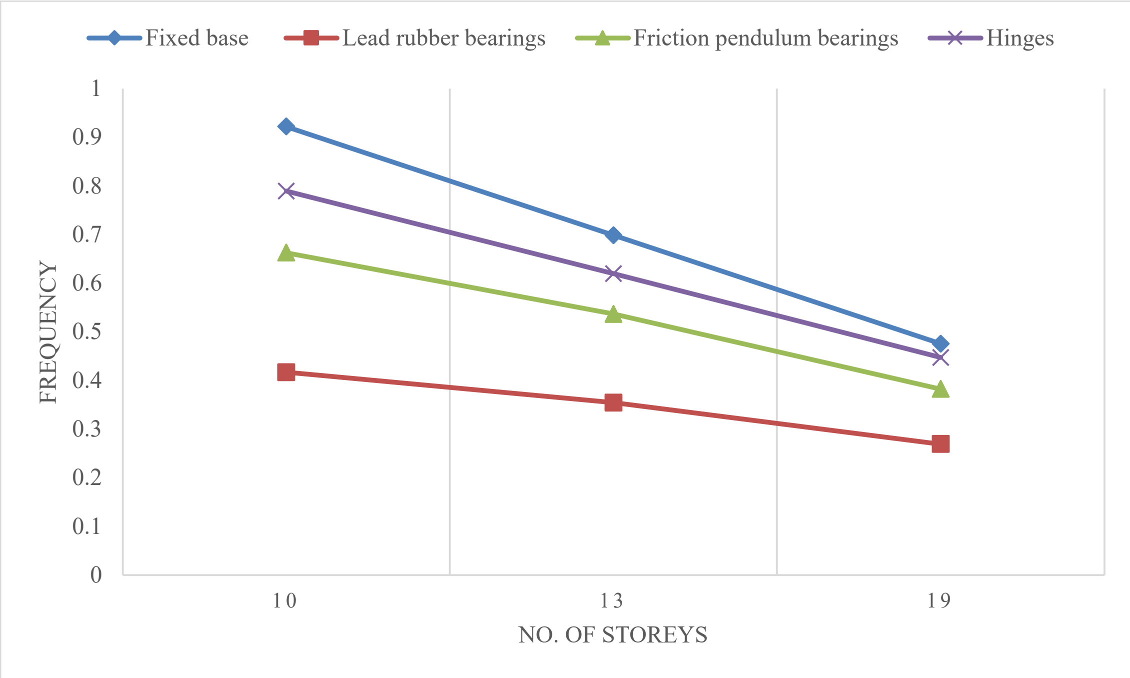



**Figure 4.73:** Frequency Based on the No. of Storeys and Different Types of Isolators

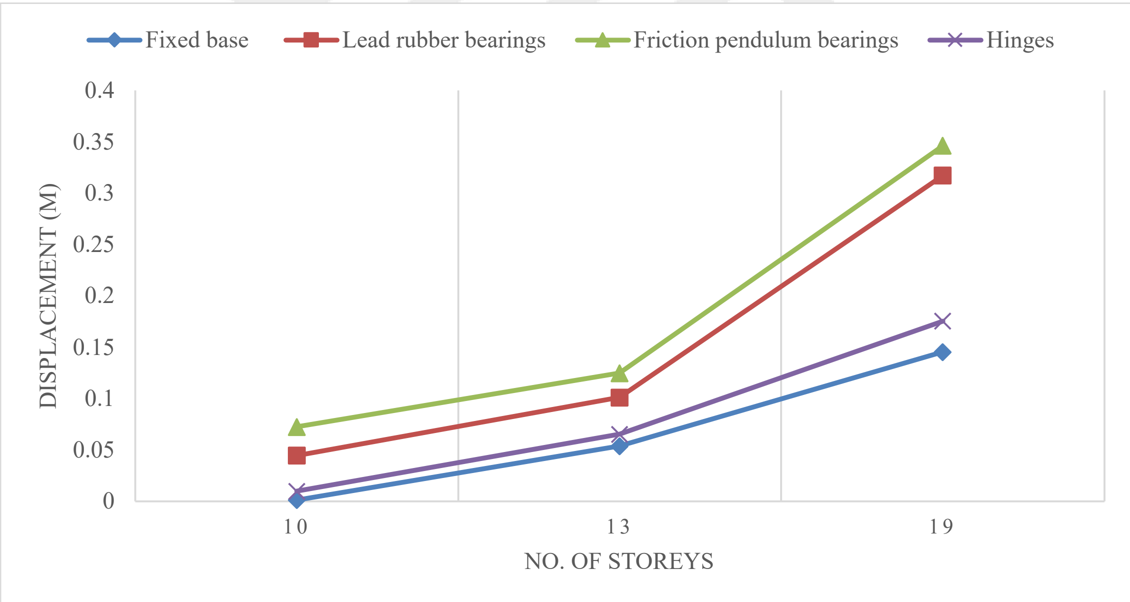



**Figure 4.74:** Roof Displacements in X Direction Based on the No. of Storeys and Different Types of Isolators

### 4.5.2 Storey Drift of the Building's Hybrid Construction (25% RC, and 75% Steel)

a. As shown in Figure 4.76, The value of storey drift decreased compared Fixed buildings with Lead rubber bearing and the Friction pendulum system by (269%, &

80%) respectively, While Hinge base increased by (36 %) compared Fixed buildings, when the No. of storeys were 10.

b. As shown in Figure 4.77, The value of storey drift decreased compared Fixed buildings with Lead rubber bearing and the Friction pendulum system by (25%, & 35%) respectively, While Hinge base increased by (14 %) compared Fixed buildings, when the No. of storeys were 13.

c. As shown in Figure 4.78, The value of storey drift decreased compared Fixed buildings with Lead rubber bearing and the Friction pendulum system by (112%, & 45%) respectively, While Hinge base increased by (10 %) compared Fixed buildings, when the No. of storeys were 19.

d. As shown in Figure 4.76, 4.77, and 4.78, the value of story drift increased by (64%, and & 112%) when the No. of storeys increased from 10 to (13 & 19) respectively, when use Fixed building, while its value decreased by (56%, and 75%) respectively, when use Lead rubber bearing, its value decreased by (6%, & 66%) respectively when use the Friction pendulum system, also its value increased by (123%, & 141%) respectively, when use Hinge base.

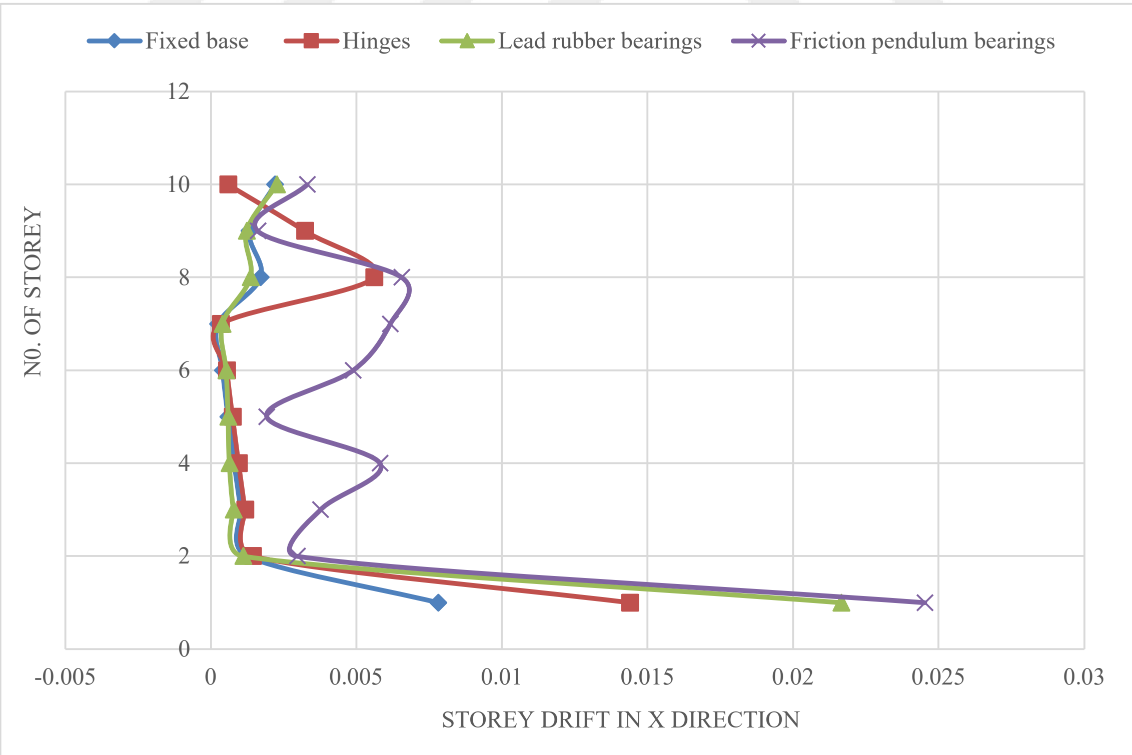



**Figure 4.75:** Storey Drift in X Direction When the No. of Storeys were 10.

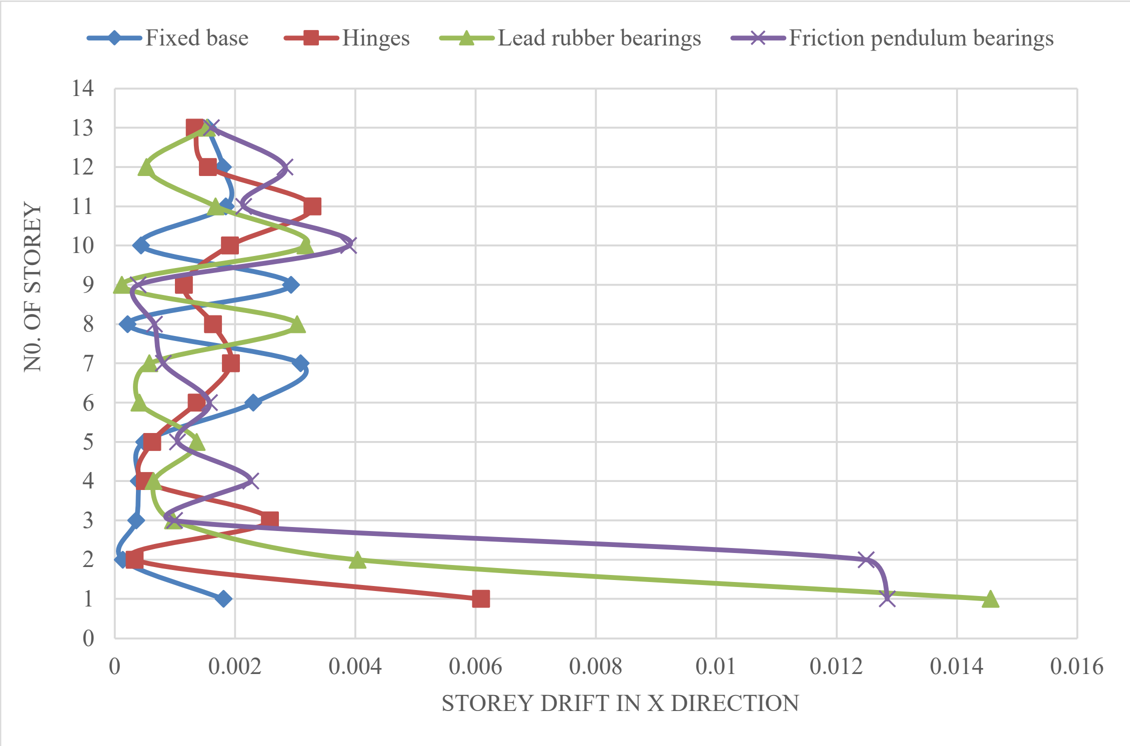



**Figure 4.76:** Storey Drift in X Direction When the No. of Storeys were 13.

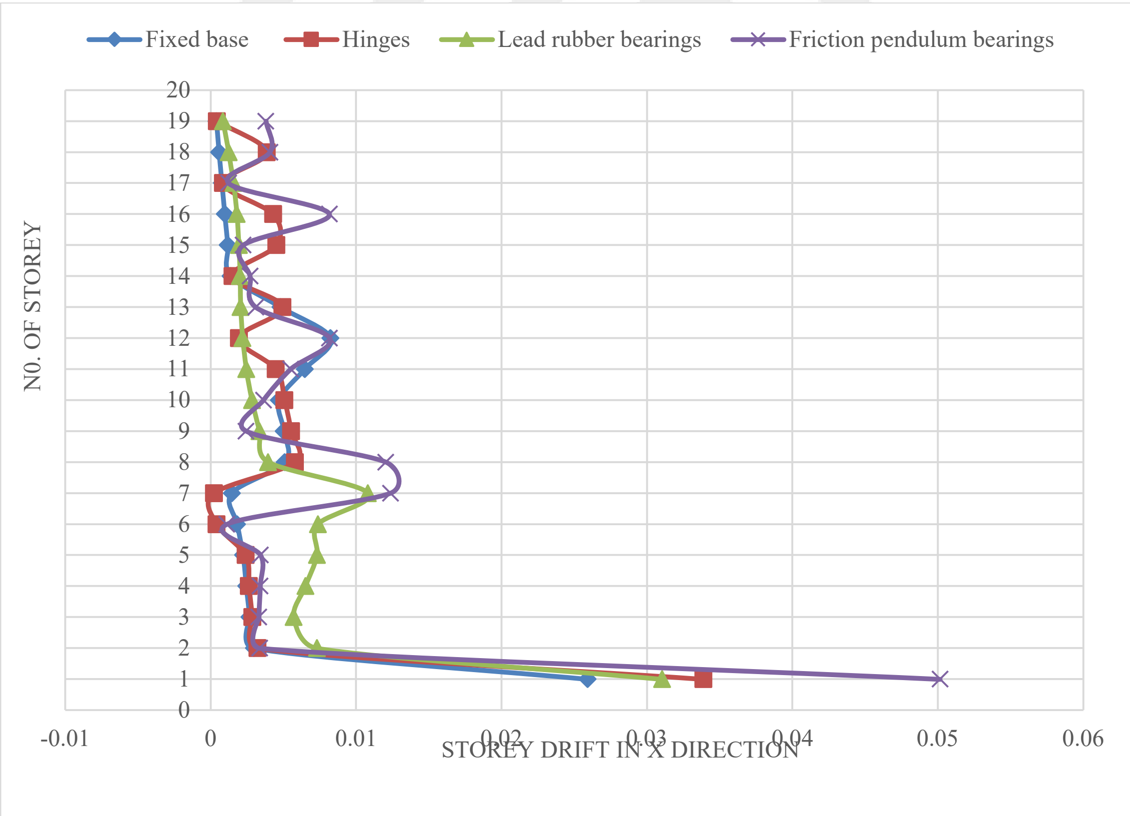



**Figure 4.77:** Storey Drift in X Direction When the No. of Storeys were 19.

### 4.6 COMPARISON OF DIFFERENT INSULATION WITH DIFFERENT CONSTRUCTION SYSTEMS (RC WITHOUT SHEAR WALL, RC WITH SHEAR WALL, STEEL, AND HYBRID CONSTRUCTION)

Comparison The value of the base shear, Time period, frequency, and displacements of different insulation with different construction systems RC (without shear wall), RCSH (with shear wall), steel, and hybrid construction),

a. Table 4.5 show Effect of Fixed base with different construction systems RC (without shear wall), RCSH (with shear wall), steel, and hybrid construction).

b. Table 4.6 show Effect of Lead rubber bearings with different construction systems RC (without shear wall), RCSH (with shear wall), steel, and hybrid construction.

c. Table 4.7 show Effect of Friction pendulum bearings with different construction systems RC (without shear wall), RCSH (with shear wall), steel, and hybrid construction).

d. Table 4.8 show Effect of Hinges with different construction systems RC (without shear wall), RCSH (with shear wall), steel, and hybrid construction).

**Table 4.5 :** Effect of Fixed Base with Different Construction Systems RC (without Shear Wall)، RCSH (with Shear Wall)، steel, and Hybrid Construction

| Compared the (RCSH, steel, and hybrid) buildings with RC buildings | | | | | |
|---|---|---|---|---|---|
| | No. of Figure | storey level | RCSH % | STEEL % | HYBRID % |
| Base shear | 4.79 | 10 | +29 | -18 | -8 |
| | | 13 | +36 | -5 | -5 |
| | | 19 | +19 | -40 | -25 |
| Time period | 4.80 | 10 | -62 | -60 | -26 |
| | | 13 | -56 | -55 | -21 |
| | | 19 | -46 | -40 | -28 |
| Frequency | 4.81 | 10 | 166 | 30 | 34 |
| | | 13 | 128 | 25 | 29 |
| | | 19 | 85 | 19 | 26 |
| Displacement | 4.82 | 10 | -90 | 66- | -99 |
| | | 13 | -83 | -51 | -46 |
| | | 19 | -80 | -67 | -43 |
| (-)mean decreased | | | (+)mean increased | | |

**Table 4. 6:** Effect of Lead Rubber Bearings with Different Construction Systems RC (without Shear Wall), RCSH (with Shear Wall), Steel, and Hybrid Construction

| **Compared the (RCSH, steel, and hybrid) buildings with RC buildings** | | | | | |
|---|---|---|---|---|---|
| | No. of Figure | storey level | RCSH % | STEEL % | HYBRID % |
| Base shear | 4.83 | 10 | +29 | -9 | -16 |
| | | 13 | +34 | -30 | -20 |
| | | 19 | +2 | -35 | -15 |
| Time period | 4.84 | 10 | +5 | -8 | -8 |
| | | 13 | +2 | -10 | -8 |
| | | 19 | -52 | -15 | -5 |
| Frequency | 4.85 | 10 | -3 | 9 | 9 |
| | | 13 | -2 | 12 | 8 |
| | | 19 | +33 | 15 | 6 |
| Displacement | 4.86 | 10 | -25 | -27 | -54 |
| | | 13 | -42 | -51 | -42 |
| | | 19 | -69 | -55 | -20 |
| (-)mean decreased | | | (+)mean increased | | |

**Table 4.7:** Effect of Friction Pendulum Bearings with Different Construction Systems RC (without Shear Wall), RCSH (with Shear Wall), Steel, and Hybrid Construction

| **Compared the (RCSH, steel, and hybrid) buildings with RC buildings** | | | | | |
|---|---|---|---|---|---|
| | No. of Figure | storey level | RCSH % | STEEL % | HYBRID % |
| Base shear | 4.87 | 10 | -20 | -65 | -62 |
| | | 13 | -10 | -67 | -63 |
| | | 19 | -25 | -70 | -64 |
| Time period | 4.88 | 10 | -17 | -1 | -5 |
| | | 13 | -19 | -5 | -8 |
| | | 19 | -21 | -8 | -10 |
| Frequency | 4.89 | 10 | 20 | 2 | 5 |
| | | 13 | 24 | 4 | 10 |
| | | 19 | 27 | 6 | 12 |
| Displacement | 4.90 | 10 | 31 | -6 | -8 |
| | | 13 | 12 | -25 | -14 |
| | | 19 | -15 | -32 | -8 |
| (-)mean decreased | | | (+)mean increased | | |

**Table 4.8 :** Effect of Hinges with Different Construction Systems RC (without Shear Wall), RCSH (with Shear Wall), Steel, and Hybrid Construction

| Compared the (RCSH, steel, and hybrid) buildings with RC buildings | | | | | |
|---|---|---|---|---|---|
| | No. of Figure | storey level | RCSH % | STEEL % | HYBRID % |
| Base shear | 4.91 | 10 | 21 | -16 | -5 |
| | | 13 | 40 | -5 | -8 |
| | | 19 | 23 | -37 | -15 |
| Time period | 4.92 | 10 | -60 | -2 | -6 |
| | | 13 | -53 | -4 | -8 |
| | | 19 | -44 | -10 | -12 |
| Frequency | 4.93 | 10 | 149 | 2 | 8 |
| | | 13 | 117 | 5 | 10 |
| | | 19 | 81 | 9 | 15 |
| Displacement | 4.94 | 10 | -90 | -43 | -85 |
| | | 13 | -80 | -31 | -30 |
| | | 19 | -85 | -60 | -25 |
| (-)mean decreased | | | (+)mean increased | | |

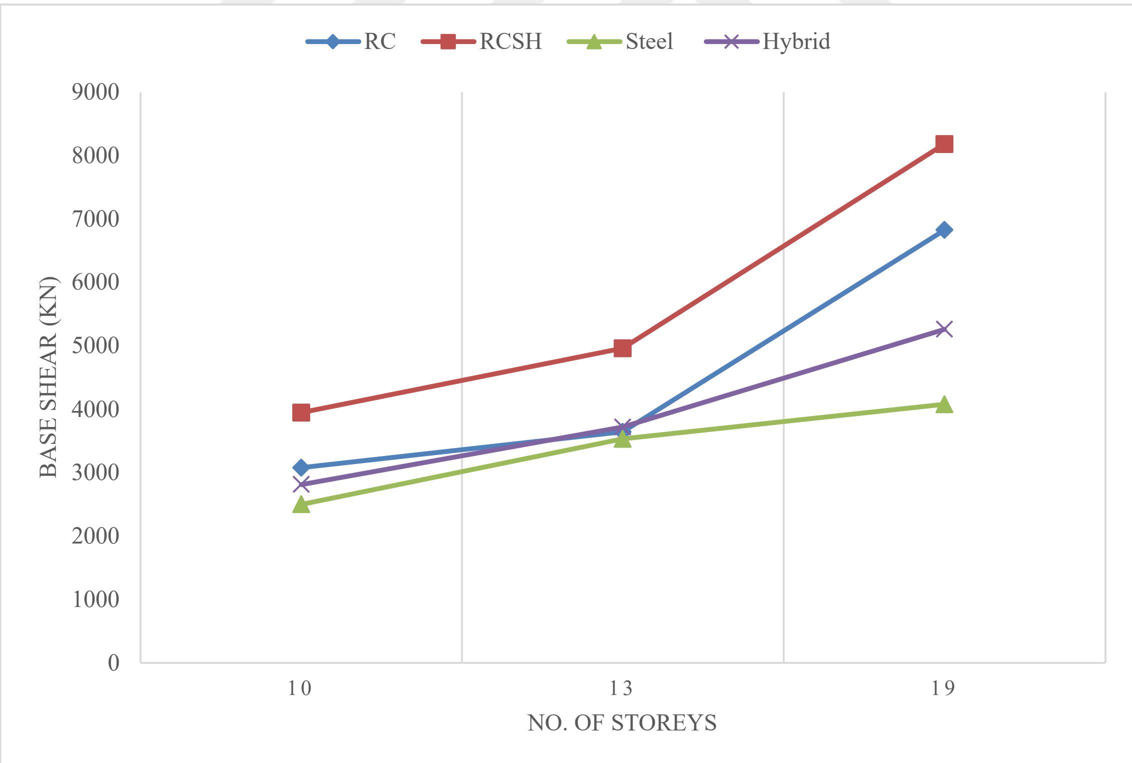



**Figure 4.78:** Maximum Base Shear Based on the No. of Storeys and Fixed Base

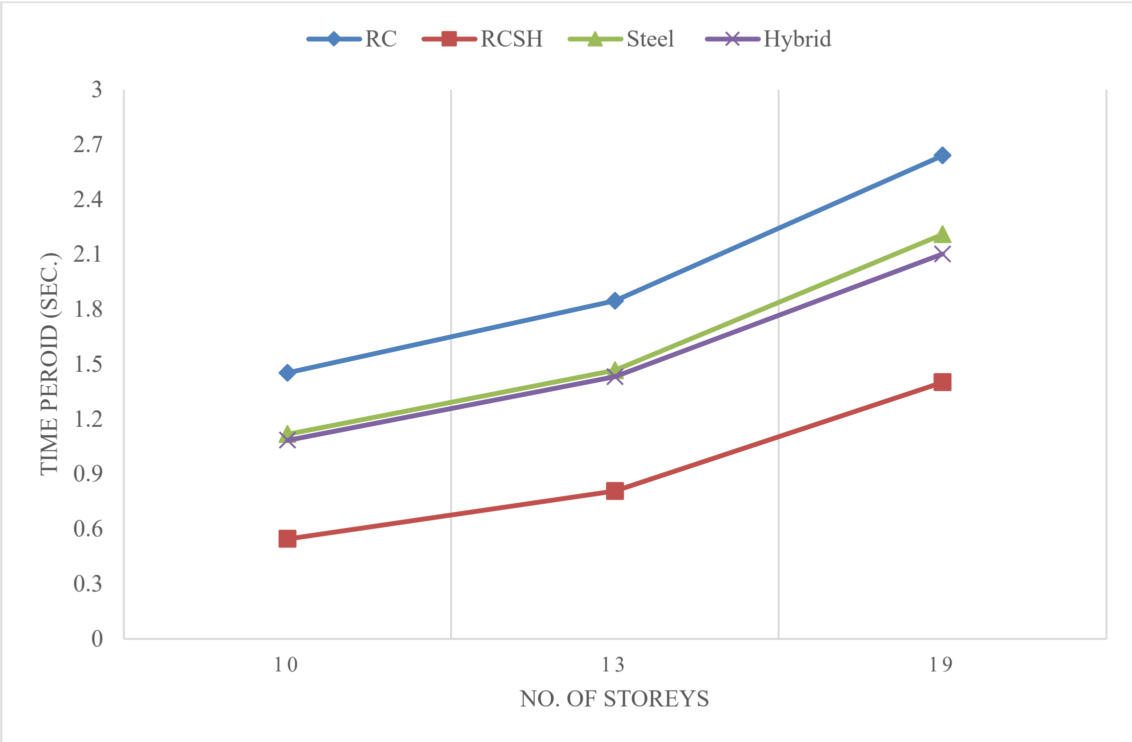



**Figure 4.79:** Time Period Based on the No. of Storeys and Fixed Base

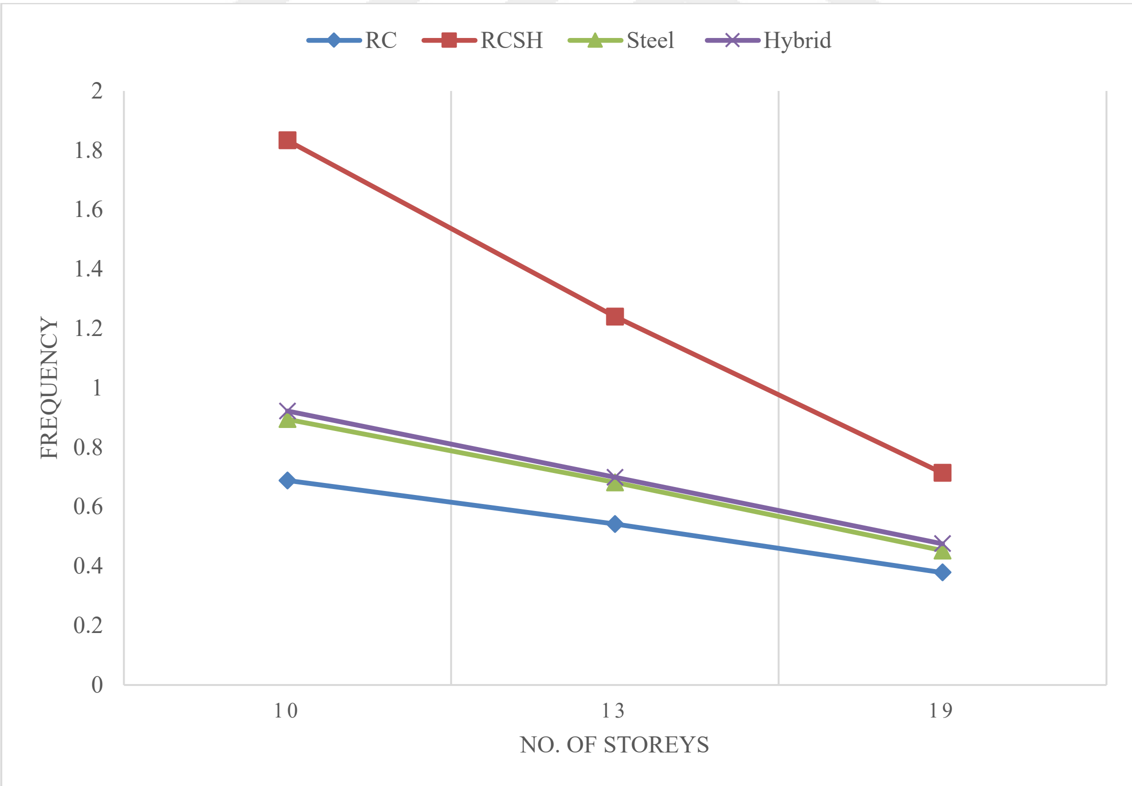



**Figure 4.80:** Frequency Based on the No. of Storeys and Fixed Base

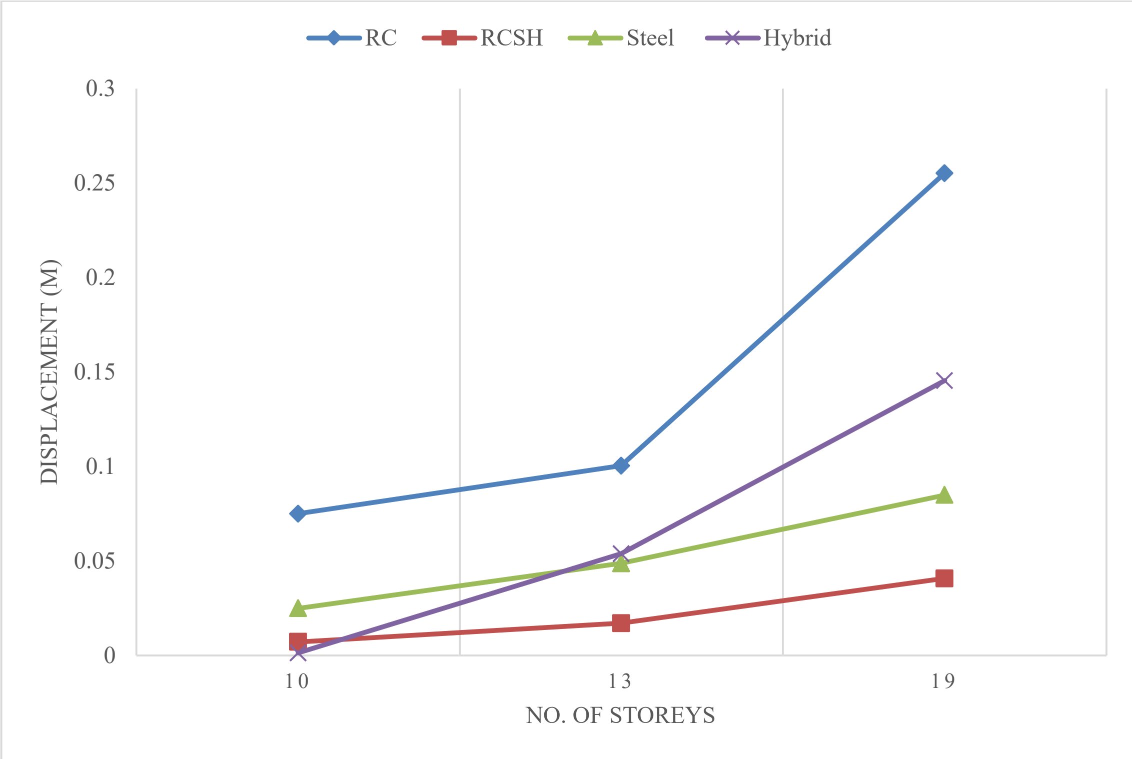



**Figure 4.81:** Roof Displacements in X Direction Based on the No. of Storeys and Fixed Base

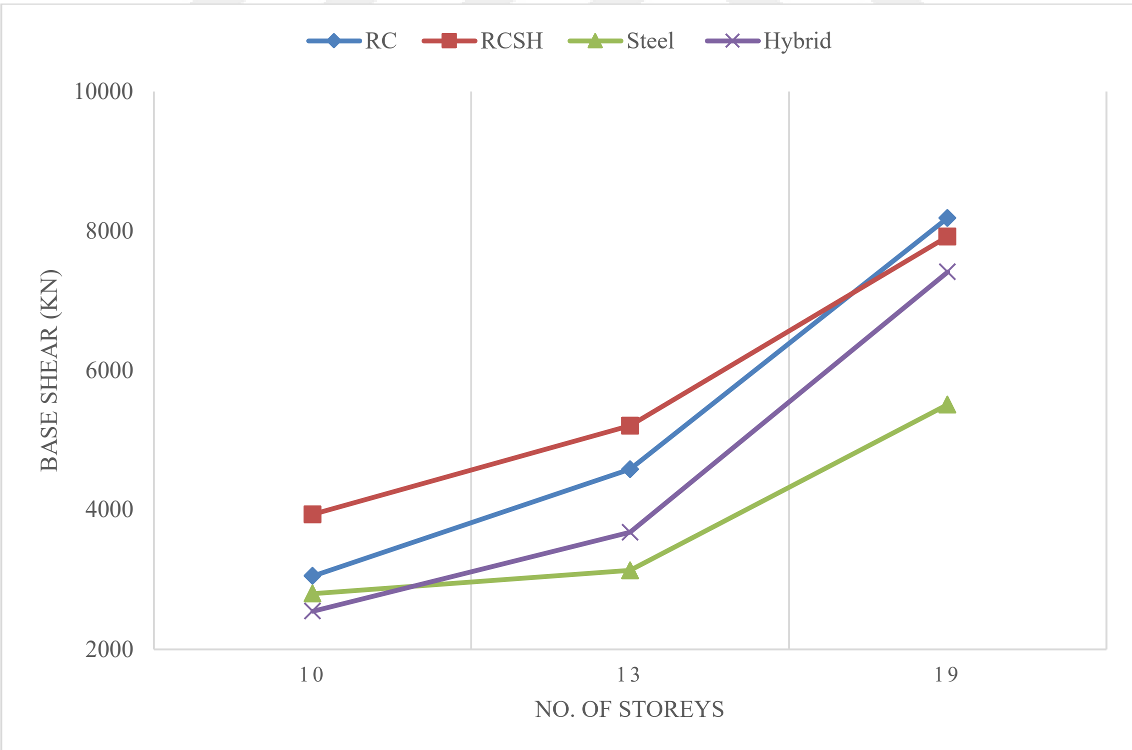



**Figure 4.82:** Maximum Base Shear Based on the No. of Storeys and Lead Rubber Bearings

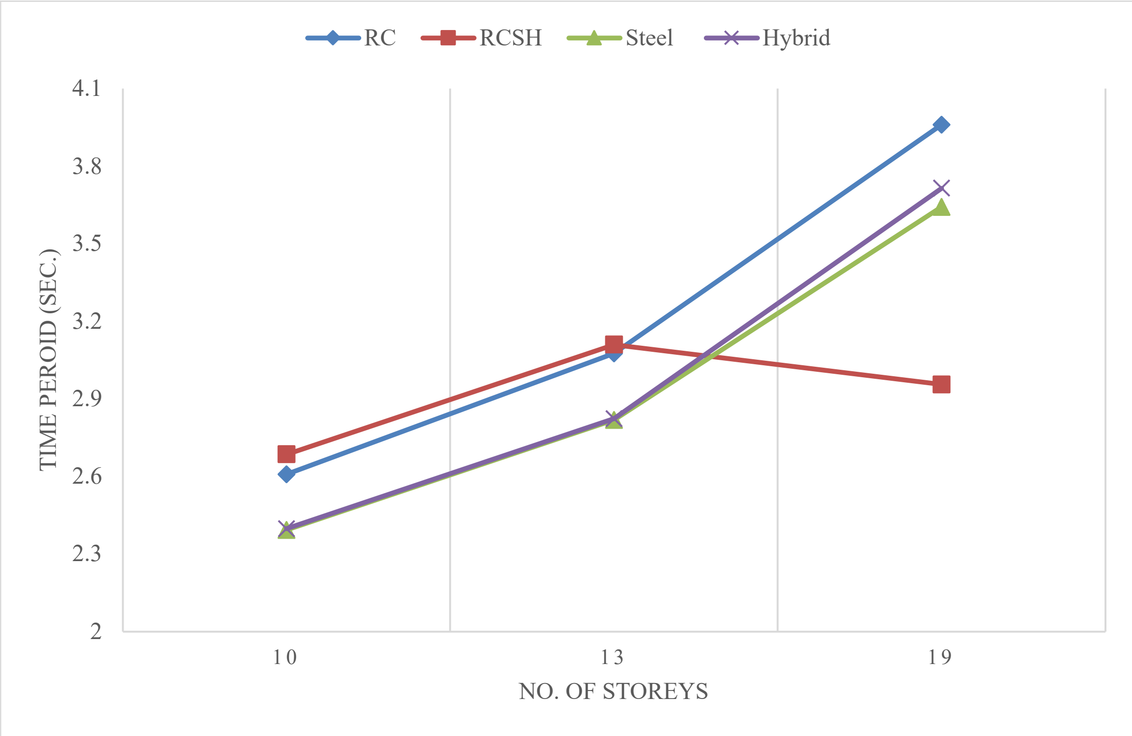



**Figure 4.83:** Time Period Based on the No. of Storeys and Lead Rubber Bearings.

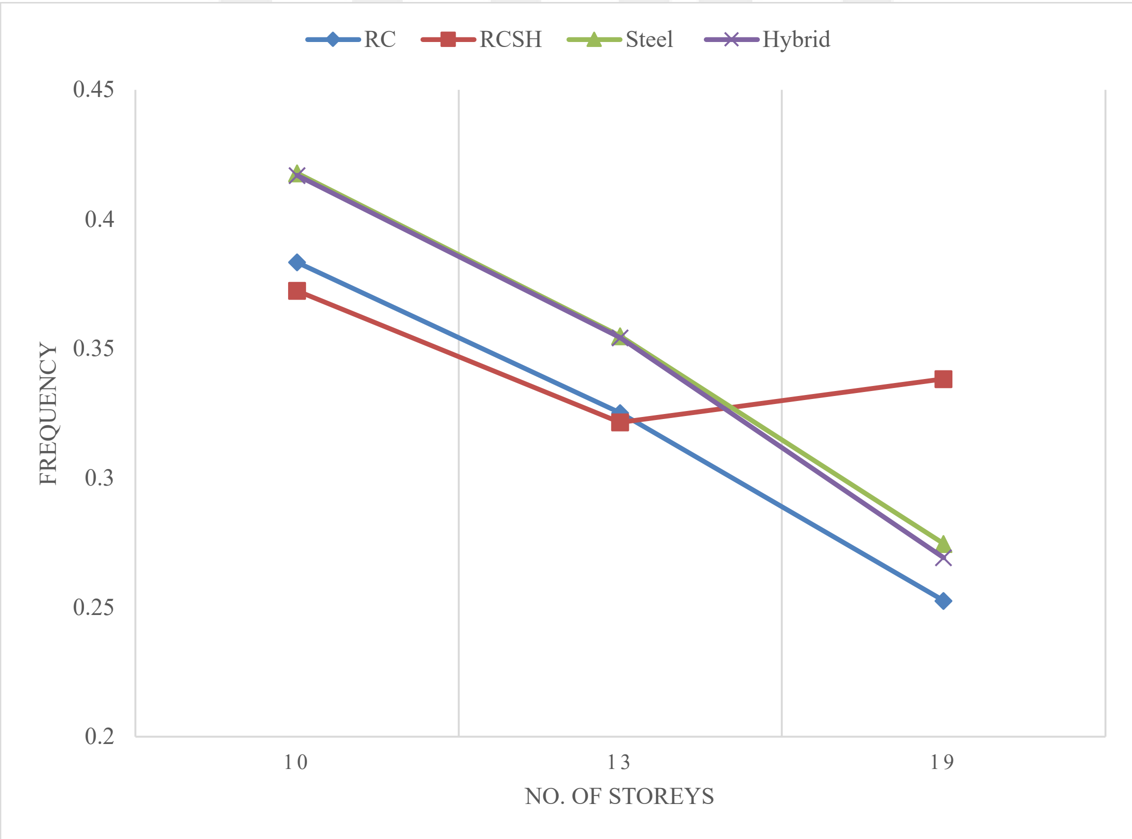



**Figure 4.84:** Frequency Based on the No. of Storeys and Lead Rubber Bearings

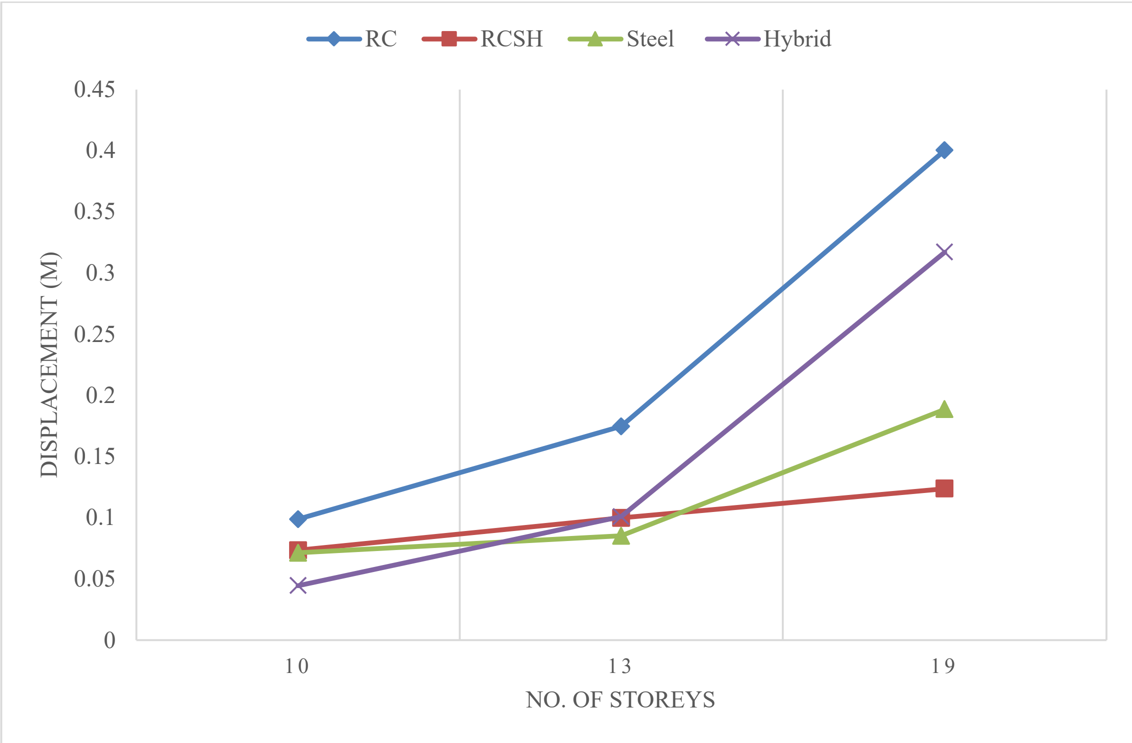



**Figure 4.85:** Roof Displacements in X Direction Based on the No. of Storeys and Lead Rubber Bearings.

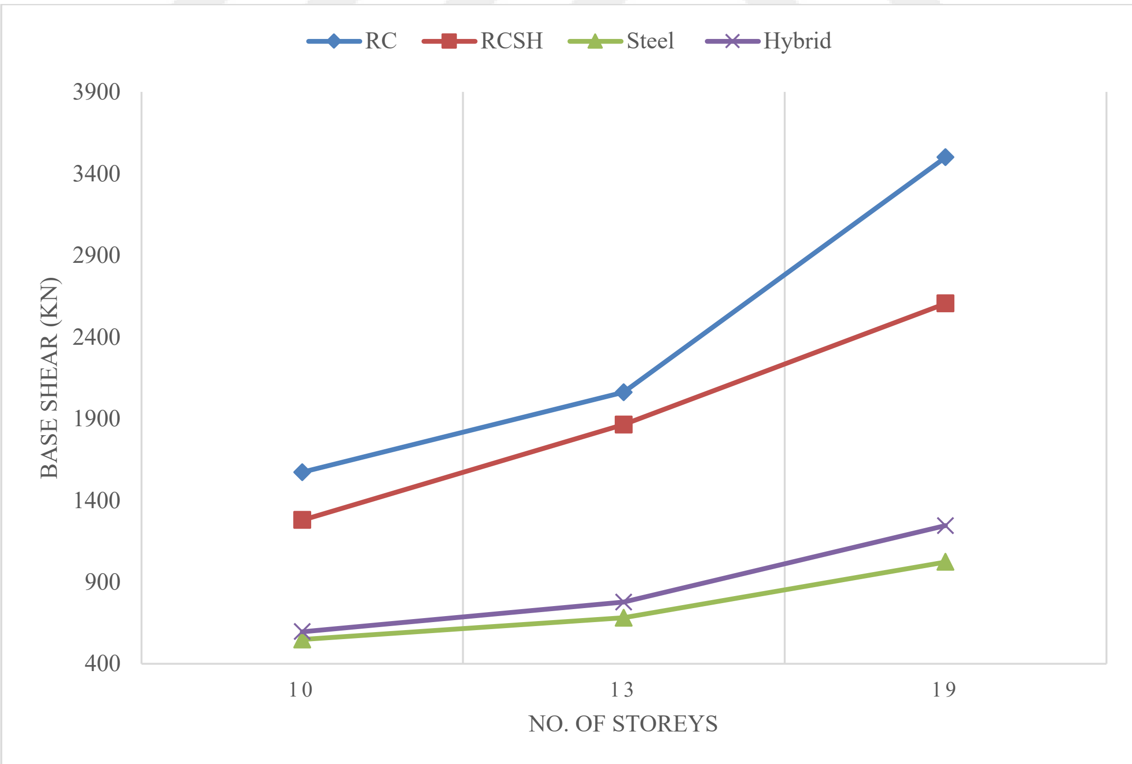



**Figure 4.86:** Maximum Base Shear Based on the No. of Storeys and Friction Pendulum Bearings.

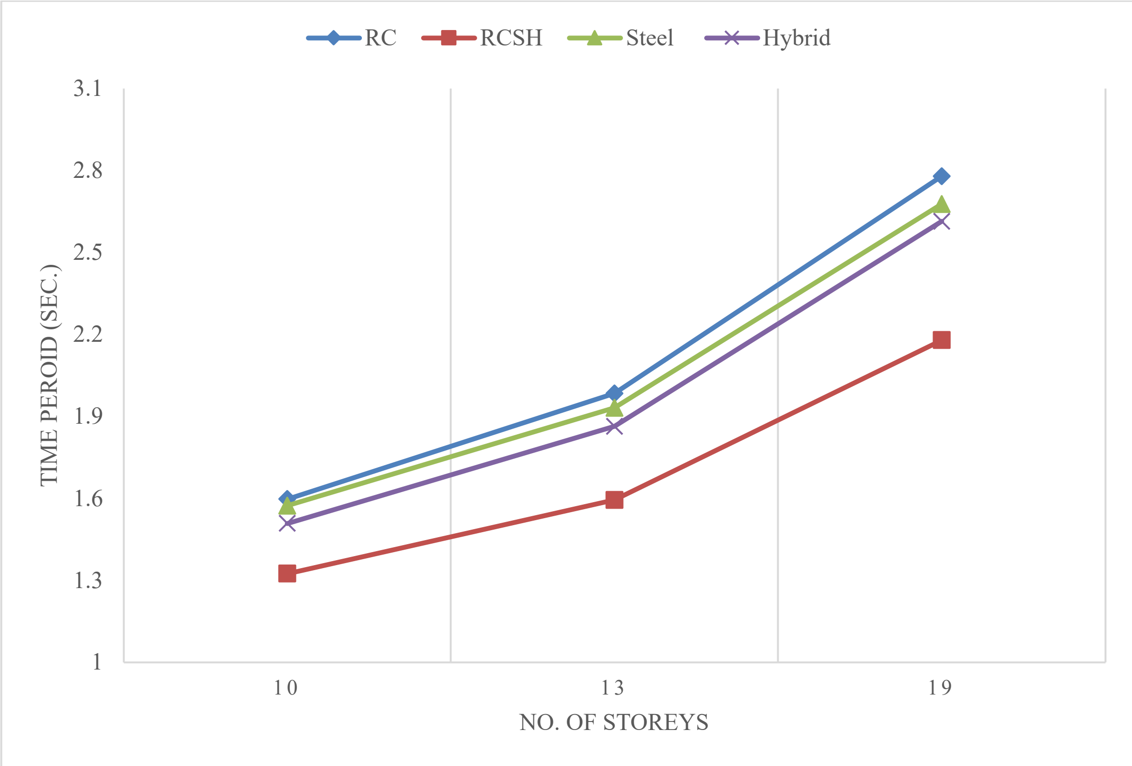



**Figure 4.87:** Time Period Based on the No. of Storeys and Friction Pendulum Bearings

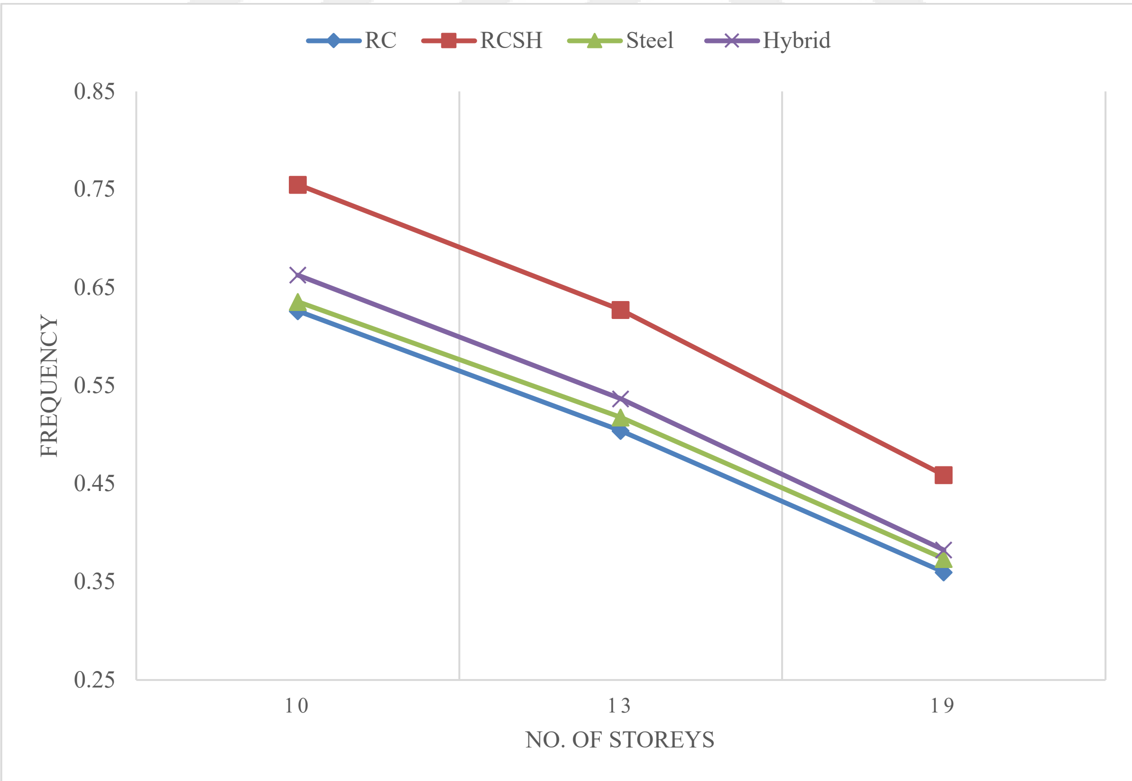



**Figure 4.88:** Frequency Based on the No. of Storeys and Friction Pendulum Bearings

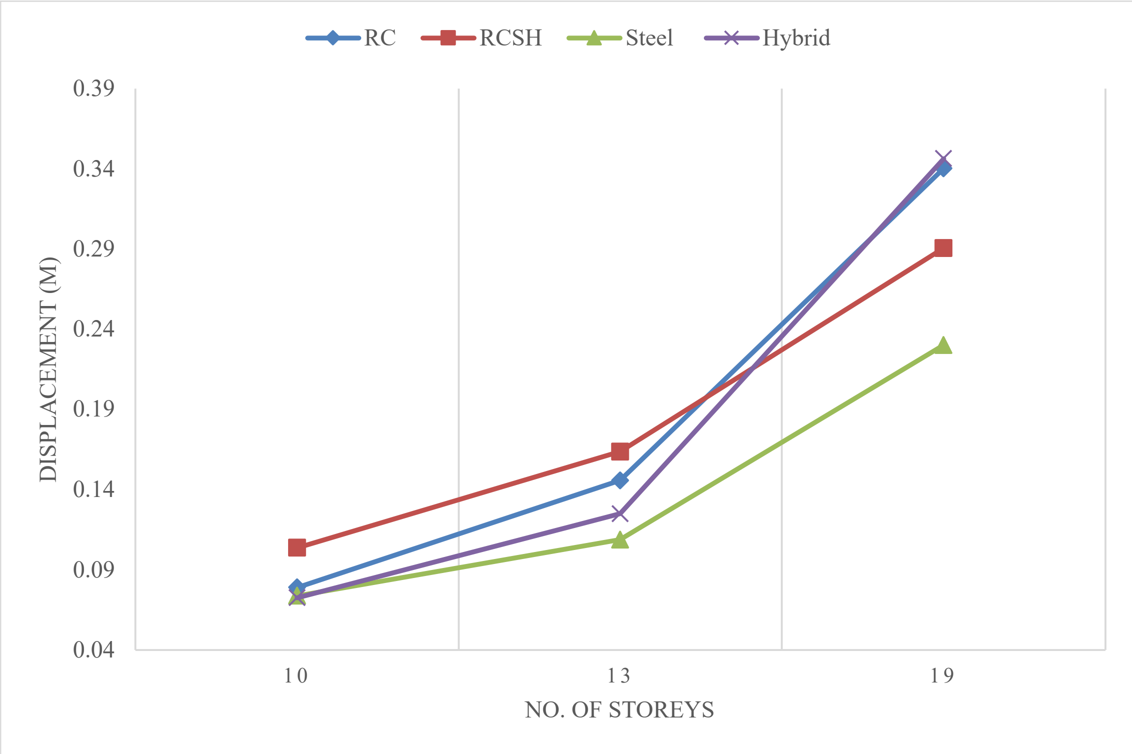



**Figure 4.89:** Roof Displacements in X Direction Based on the No. of Storeys and Friction Pendulum Bearings.

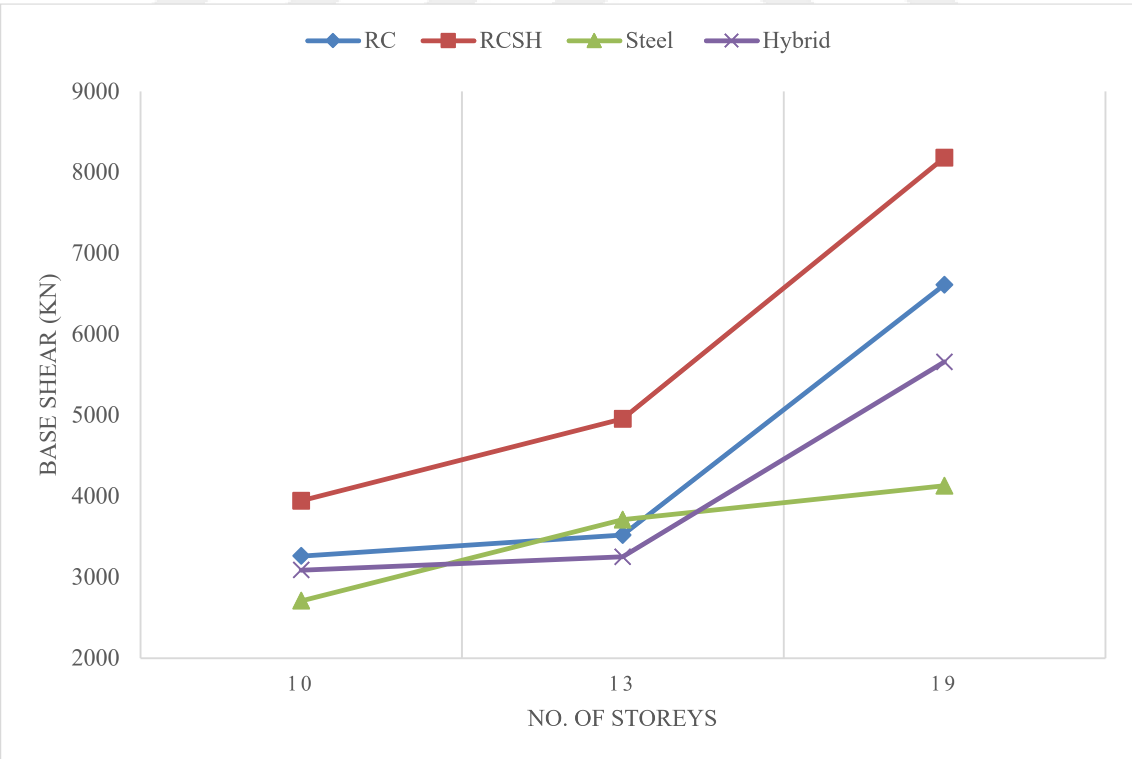



**Figure 4.90:** Maximum Base Shear Based on the No. of Storeys and Hinges.

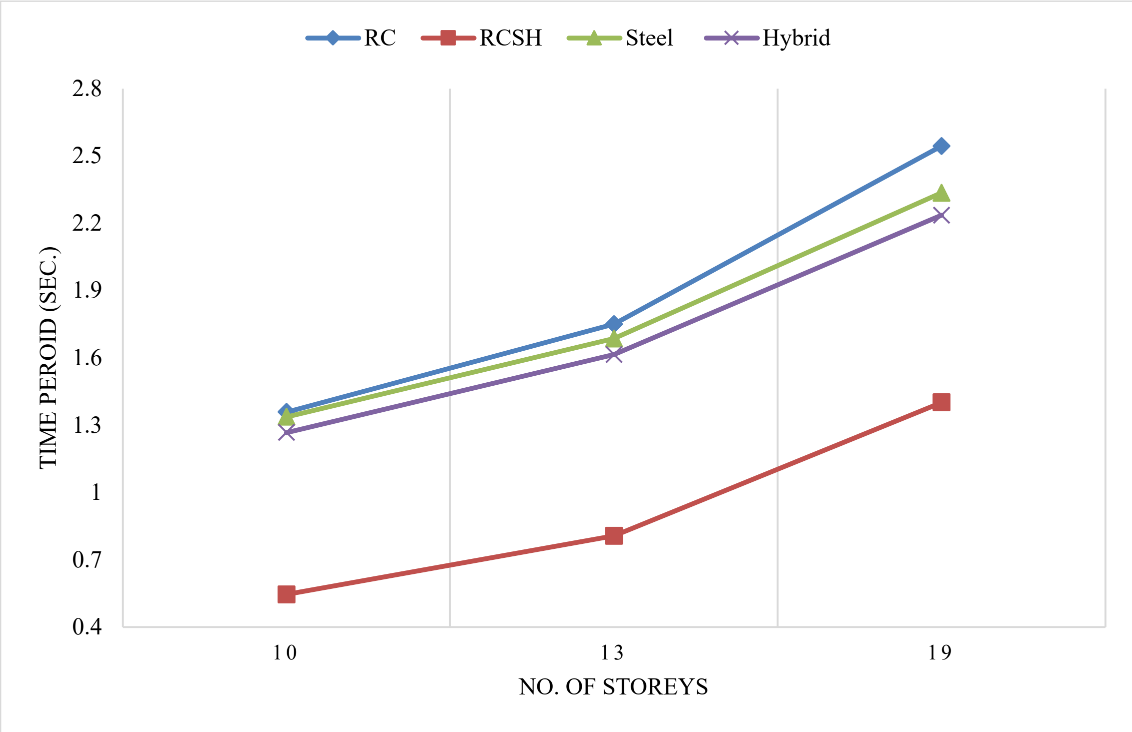



**Figure 4.91:** Time Period Based on the No. of Storeys and Hinges

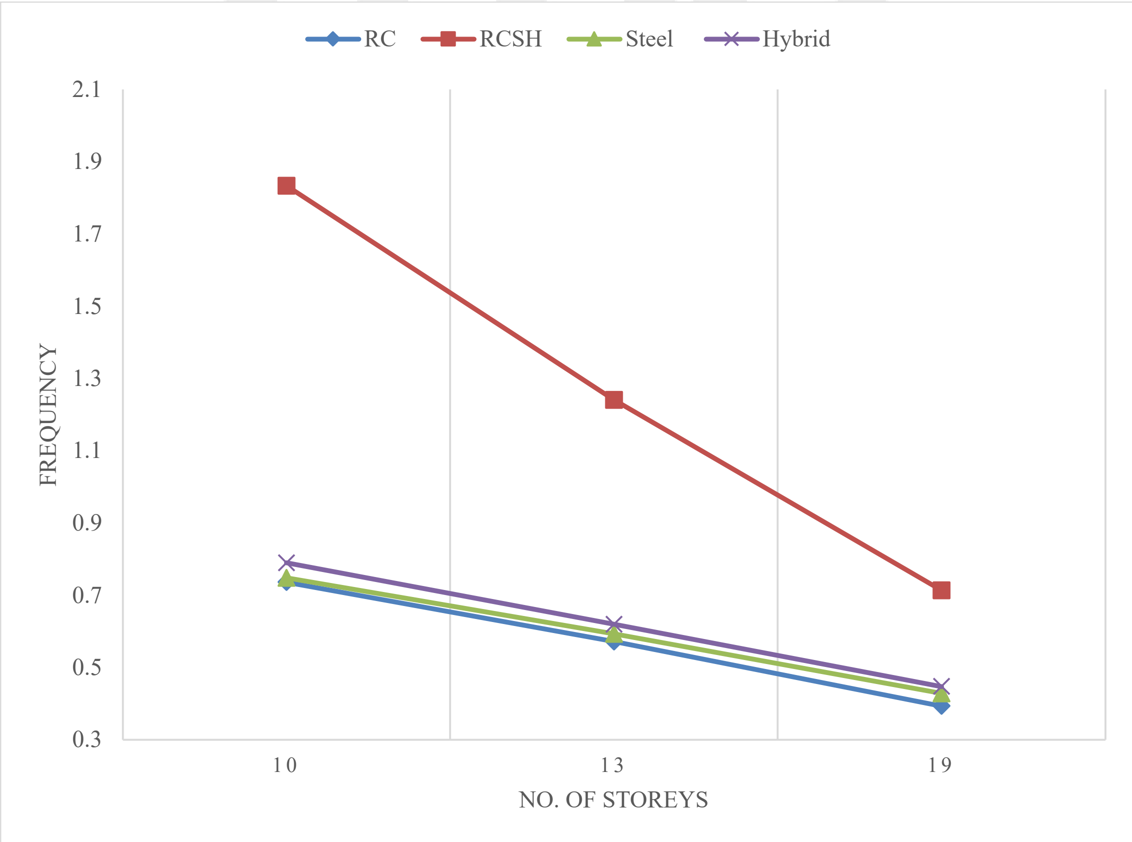



**Figure 4.92:** Frequency Based on the No. of Storeys and Hinges

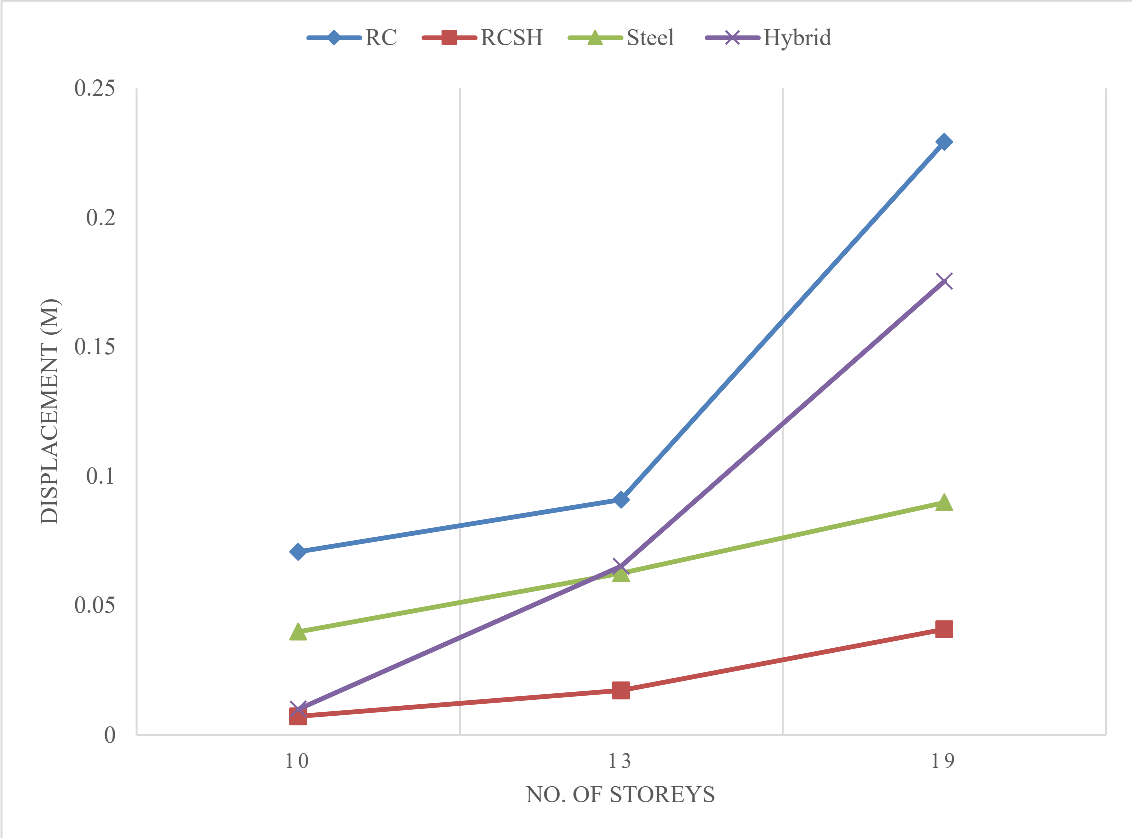


**Figure 4.93:** Roof Displacements in X Direction Based on the No. of Storeys and Hinges

# 5. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE WORKS

## 5.1 CONCLUSIONS

This study attempts to comprehend the sufficiency of the base disconnecting component for a quake. This study deals with the dynamic response of multistory buildings with different types of isolators. A nonlinear, time-history analysis has been done using the finite element method with SAP2000 software. This study yielded numerous calculations, which can be summarized as follows:

a. SAP2000 software was used to perform validation studies for RC building analysis, with data obtained from previous literature, and the error rate of validation models studied in Chapter 3, did not exceed 3%.
b. From the Time history analysis of the RC buildings without shear wall, the main effects of isolating the bases of the building for the nonlinear analysis, may be stated as:

i. The isolation by LRB causes a reduction in Frequency by (50%), and increased base shear, time period, displacements, and storey drift by (22%, 148%, 93%, and 60%) respectively.
ii. The isolation by FPS causes a reduction in Frequency and base shear by (18%, and 72) respectively, and increased, time period, displacements and storey drift by (52%, 88%, and 45%) respectively.
iii. The isolation by Hinge base causes a reduction in storey drift by (27%), and increased, time period, displacements, Frequency, and base shear by (25%, 12%, 10%, and 12%) respectively.
iv. The value of the base shear, Time period and displacements increased as the No. of storeys increased, while the value of frequency decreased as the No. of storeys increased. The increase of base shear due to increase the height of building.
v. The base shear, time period and roof displacements values increased when the No. of bay increased. However, it may lead to made to redistribution the internals forces and re-arranged the location of plastic hinges

c. From the Time history analysis of the RC buildings with shear wall, the main effects of isolating the bases of the building for the nonlinear analysis, may be stated as:

i. Generally, the isolation of the buildings with the presence of shear walls causes a decrease in the natural periods, and displacements compared with the buildings without the presence of shear walls and the decrease in the natural period is clearer in a low-rise building (7 storeys) than a high rise (19 storeys).

ii. The isolation of the buildings with the presence of shear walls causes a increase in the base shear compared with the buildings without the presence of shear walls and the increase in the base shear is clearer in high rise (19 storeys).

iii. The isolation of the buildings with the presence of shear walls causes a increase in the Frequency compared with the buildings without the presence of shear walls and the increase in the Frequency clearer in a low-rise building (7 storeys) than a high rise (19 storeys).

iv. The value of the base shear, Time period and displacements increased as the No. of storeys increased, while the value of frequency decreased as the No. of storeys increased, the base shear, time period and roof displacements values increased when the No. of bay increased. However, it may lead to made to redistribution the internals forces and re-arranged the location of plastic hinges

v. The value of storey drift decreased compared Fixed buildings with Lead rubber bearing and the Friction pendulum system by (20%, & 30%) respectively, While Hinge base increased by (10%) compared Fixed buildings, when the No. of storeys were 7.

vi. When using shear wall, the value of story drift decreased by (70%, 37%, 1083% & 1309%), when use (The Friction pendulum system, Lead rubber bearing, Fixed base, and Hinge base) respectively comparison without shear wall.

d. The main effects of isolating the bases of the building's hybrid construction (25% RC, and 75% steel) in comparison with fixed building, may be stated as:

i. The isolation by LRB causes a reduction in Frequency, and base shear by (54%, & 15), and increased, time period, displacements, and storey drift by (121%, 88%, and 269%) respectively.

ii. The isolation by FPS causes a reduction in Frequency, base shear, and storey drift by (28%, 20%, & 80%) respectively, and increased, time period, and displacements by

(40%, &132%) respectively.

iii. The isolation by Hinge base causes a reduction in Frequency by (15%) respectively, and increased, storey drift, and time period by (36%, & 18%)

e. When comparing the structure in terms of composition (comparing concrete buildings without shear walls with concrete buildings with shear walls, steel buildings, hybrid buildings) with each isolation method separately, it was found:

i. Fixed buildings, when comparing concrete buildings without shear walls with concrete buildings with shear walls, steel buildings and hybrid buildings. It was found that the base shear value increased by (36%, 40%, and 23%) respectively, the time period value decreased by (62%, 40%, and 20%) respectively, and the displacement decreased by (90%, 51%, and 67%) respectively.

ii. buildings isolated with Lead rubber bearing base, when comparing concrete buildings without shear walls with concrete buildings with shear walls, steel buildings and hybrid buildings. It was found that the base shear value changed by (+34%, -33%, and -20%) respectively, the time period value decreased by (52%, 10%, and 8%) respectively, and the displacement decreased by (69%, 50%, and 20%) respectively.

iii. buildings isolated with Friction pendulum system base, when comparing concrete buildings without shear walls with concrete buildings with shear walls, steel buildings and hybrid buildings. It was found that the base shear value decreased by (25%, 70%, and 64%) respectively, the time period value decreased by (21%, 5%, and 10%) respectively, and the displacement decreased by (12%, 25%, and 15%) respectively.

iv. buildings isolated with Hinge base, when comparing concrete buildings without shear walls with concrete buildings with shear walls, steel buildings and hybrid buildings. It was found that the base shear value changed by (+21%, -37%, and -15%) respectively, the time period value decreased by (60%, 15%, and 10%) respectively, and the displacement decreased by (90%, 43%, and 30%) respectively.

f. Fixed base building has zero displacement at base whereas, base isolated building shows appreciable number of lateral displacements at base (due to presence of Base Isolator). Fixed support system is not preferred for seismic loadings due to the story drifts are more than other bearing support types

g. The friction pendulum support has been preferred type due to the lowest drift story of building when it compared with other support system. The inclusion of the shear wall causes an increase in the base shear. This increase in the fixed base buildings is more than that of the isolated one.

h. The combination of steel and concrete for the development of innovative hybrid structural systems appears to be a promising way to design against Earthquake load in an effective.
i. The increase of base shear due to increase the height of building, also the increase lateral displacements of the buildings, and the increases in time period due to decrease the stiffness of RC building and it have more displacements at tip of buildings
j. As the span length increased, the values for the base shear, time period, and roof displacements all rose. The internal forces may need to be redistributed, and the position of the plastic hinges may need to be adjusted as a result. This effect can be attributed to the fact that lengthening beams in the RC building under study causes their lateral stiffness to decrease.
k. Finally, it is concluded that base isolation system is significantly effective to protect the structures against strong earthquake ground motion.
l. Steel and reinforced concrete are combined in composite or mixed structural systems. This combination generally results is greater economy and safety than could be achieved by either material alone. However, the combination of two dissimilar materials results in serious design problems.

### 5.2 RECOMMENDATIONS FOR FUTURE WORKS

For future research, some recommendations may be stated as follows:

a. Further research is required to investigate the influence of soil types and damping ratio on the dynamic response for the fixed and isolated base buildings.
b. Further research can be done to investigate the effectiveness of different types of isolators other than the adopted LRB, and FPS, within the story's levels.
c. A similar study can be carried out on a structure studied with response spectrum analysis
d. Further research is required to analysis hybrid building consist of filled and partially filled brick or masonry walls.
e. It is recommended to implement this study on RC multistory building having prestressed beams and slabs and limit the adjusted parameters.

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